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ENERGY EFFICIENCY IMPROVEMENT IN ANODE BAKING FURNACES

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Abstract

Energy Efficiency is currently the biggest challenge in the Aluminum Industry. One of the high energy consumption facilities in a smelter is the Anode Baking Furnace (ABF). Due to unavailability of natural gas in the region, Alumar ABF uses Diesel oil, which increases significantly the energy costs. This paper describes how a different technical approach led to improved energy efficiency and reduced costs. Changes in process parameters, maintenance strategy and operational training were the main enablers.

Technology Team worked to improve the draft control in the pre-heating zone, enabling the Baking Temperature Curve optimization, without compromising anode quality. The new curve allowed the soaking time and the number of fire frames to be reduced, reducing significantly the energy consumption.

Introduction

For aluminum production, primary industry uses electrolytic cells to transform alumina into metallic aluminum. During this process, the cell consumes the anode, a carbon block with specific properties, needing to replace the anode blocks timely to ensure continuous production.

Carbon Plant supplies the Potrooms with anode blocks. These blocks are made of calcined coke particles glued together with pitch (green anodes) that pass through a thermal treatment to achieve the proper thermal, electrical, mechanical and chemical properties. Even raw material quality (coke and pitch) and baking process quality affect final anode block properties.

During thermal treatment, Anode Baking Furnaces (ABF) uses fuel to generate enough energy for the baking process. Thus, energy efficiency comes as an important process and financial indicator, directly related to the amount of energy (burned fuel) needed to bake a specific anode weight (GJ/MT). ABF is challenged to produce high quality anodes, with lower fuel consumption and not harming furnace refractory life.

Anode Baking Furnace Aspects

The first step of anode block production is the green anode formulation. Different grain size of coke and butts (spent anodes) are mixed to coal tar pitch, generating a block with high electrical resistivity and reactivity, and low mechanical resistance; properties that negatively impact in electrolytic cell operation.

During baking, green anodes are heated to temperatures over 1060^{o}C, calcining coke particles and pitch to achieve the properties required. Alumar conducts it in three Open Top Ring Furnaces, using diesel oil as fuel. Considering the furnace technology, the fuel burned represents 50 to 60% of energy required and the pitch tar fumes burning inside the furnace complete the total required energy. Then, an effective control of the pitch burning allows lower fuel consumption, improving Energy Efficiency (GJ/MT of baked anodes) [1].

A furnace production unit is called a “Fire”. This group of equipments is responsible to exhaust burned gas (Exhaust Manifold), input fuel by temperature control (Firing Frames), and control the negative pressure inside flues (Draft Frame) [1]. Figure 1 shows a Fire organization through Furnace Sections, indicating the proper Fire Regions.

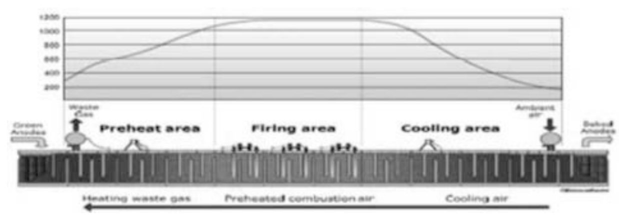

Figure 1 Fire regions and temperature curve design through them

Pre-heat area

Inside the pre-heating zone, all pitch tar fumes are burned generating energy to bake the green anodes. This mechanism directly impacts fuel efficiency (40-50% of all energy comes of green anodes pitch volatiles) [1]. Fire evolution can be controlled by the volatile burn position and gas temperature increase and it is the first step to a proper firing control.

With the proper control, the burned volatiles heat the anodes up, reducing the use of fuel to promote the baking process. The draft adjustment is the key to the pre-heat area control, enabling the Fire to achieve the required temperatures, without heat waste to the stack gas.

Firing area

In the Firing Area, there are structures called “Firing Frames” that input fuel to burn and increase temperature following a target curve. The flue temperature is measured and regulates the fuel inlet, to achieve the proper curve.

Baking and pre-heating are connected; the proper draft to take pre-heating in time permits to follow the temperature curve, with low fuel consumption and a better temperature distribution inside furnace pits. To reach better and more uniform anode properties, the first step is to control the pre-heating zone, and then to optimize baking temperature curve.

Cooling area

After thermal treatment, the baked anodes will be cooled slowly to temperatures lower than 300°C to be unloaded without risk of air burning. All of the heat from the baked anodes is used to pre-heat rich-gas that feeds the baking sections with oxygen, burning the fuel and, then, the pre-heating zone, burning the volatiles.

Improvements

Background

Alumar has 3 different furnaces with 9 production "Fires" working on them. Each furnace has its particularities; considering project, refractory life, number of fires and baking temperature curves.

During the past several years, some of the furnace equipment had its function restricted due to problems related to mechanical and electrical maintenance. At same time, the Technology Team looked for new parameters for Furnace operation. The automatic draft control system of the exhaust manifold was not able to continue operating without safety risks. Inside this situation, the Technology and Operational Teams did not have experience with manual draft control, and manifold did not have proper devices to allow valve opening adjustment manually.

Due to the above situation, draft control was not prioritized. Fires started to work with high draft, losing control of pre-heating evolution, leading baking zone to supply enough energy for the accelerated pre-heat area and achieve the final pit target temperatures desired. The main impact of that practice was higher fuel consumption and, consequently, worse energy efficiency.

Other consequence of this problem is the high temperatures seen on the flue bricks (hot spots). Burners input high amounts of fuel, and burn it right after the injection point. This condition heats up those bricks, more than all other flue bricks. If not well controlled, it can lead to fluewalls melting down and loss of refractory life.

The Alumar Anode Baking Furnace does not own a fume treatment system, so opacity and environmental emissions are important indicators of process control.

Pre-Heating Control

First step to promote improvements to the anode baking process was related to re-establish a draft control system, enabling individual flue draft set-up. The pre-heating zone did not have an efficient control, causing higher fuel consumption to supply enough heat pulled of baking due to a high draft.

The old automatic system did not work properly, so the maintenance team worked to create a new device based on manual control. Using parts of the old system, a device of simple operation was installed and permits a fine control in each flue.

With manual devices installed, the technology team began the operational training. Initially, it consisted of on-the-job training, reducing draft, controlling baking temperatures manually and solving dirty-flue problems. Next step, operators were familiarized to the new situation of pre-heating zone. In order to help the operational crew, a spreadsheet was developed, helping to achieve proper pre-heating control (Figure 2).

ACOMPANHAMENTO EVOLUÇÃO DE PRÉ-AQUECIMENTO
FORNO 3 - 24 HORAS

Data: / / TOD: MGO:

Operador	Idade Padrão	Idade Real		LEITURAS DE DRAFT, FLUES END SEAL; TEMPERATURAS							Temp MGO		Draft MGO
				Cand1	Cand2	Cand3	Cand4	Cand5	Cand6	Cand7	Real	Target	
	0		Draft									130	
			Temp. 520°C										
			Flue End Seal										
	4		Draft									163	
			Temp. 550°C										
	8		Draft									195	
			Temp. 595°C										
	12		Draft									228	
			Temp. 635°C										
	16		Draft									260	
			Temp. 700°C										
	20		Draft									293	
			Temp. 760°C										
	24		Draft									325	
			Temp. 800°C										

Figure 2 Pre-heating temperature control form

Figure 2 (above) and Figure 3 (below) show the temperature and pitch tar fumes burning evolution during all pre-heating cycle, respectively. Using them, the operational crew is able to analyze how the Fire is evolving and take actions related to draft adjustment, promoting better pre-heating control.

Figure 3 Pitch tar fumes evolution form

Baking Curve Optimization

After the new routine was established for draft and temperature control in the pre-heating zone, it was possible to work on a new temperature curve for baking zone.

All Fires used to have 4 Firing Frames, with more than 50 hours of soaking time and 1190°C of soaking temperature. First step: propose a new curve with soaking time and temperature for a 3-Firing Frames configuration (Figure 4), without negative impacts to baked anodes quality. It had immediate impact on fuel consumption and quality parameters were followed by regular properties analyses.

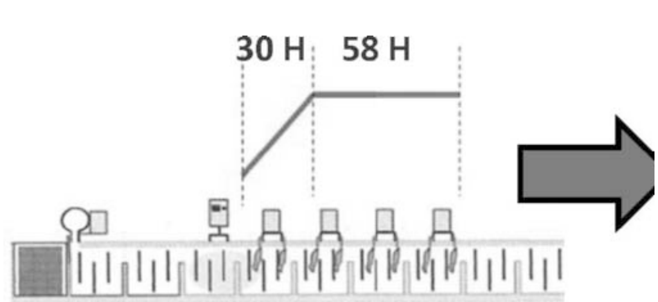

Figure 4 Baking curve optimization

Continuing the firing curve optimization, the technology team worked on the anode heat-up rate and soaking time for different fire cycles (22 hours, 24 and more than 24 hours). Operational crew received training about new curves and its relation with pre-heating and draft control.

Maintenance team improved firing frames corrective actions. Their work focused on clearing obstructed burners, cleaning fuel and steam lines, reduced fuel input problems during baking process. Maintenance team work positively influenced the baked anodes quality, enabling the technology team to work on temperature curves improvements.

Sealing and Refractories

To achieve better results for pre-heating control, furnace sealing must be in perfect condition. One important point to help the fires is to maintain, at least, 2 sections ahead of the exhaust manifolds loaded with green anodes that are properly sealed and packed with packing material. The Refractory teams worked to allow continuous operation under these conditions.

Another important point is related to Furnaces Rebuilding program, focusing in critical sections first, and changing critical flues individually. The new strategy enabled gas flow control improvements, better heat transference from flue to anodes.

Results

After all improvements implemented, the main result obtained was the improvement of Energy Efficiency, as shown on Figure 5 below.

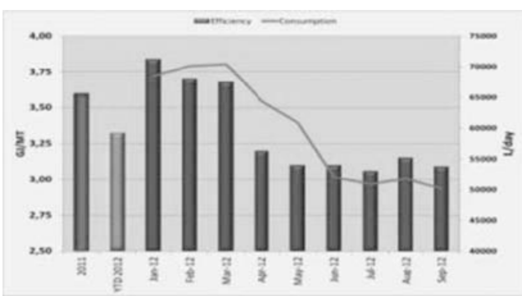

Figure 5 Results for fuel through the months

Alumar anode baking furnaces had an Energy Efficiency around 3.6 GJ/MT before the improvements, reducing it to around 3.1 GJ/MT. Fuel consumption decreased from 70,000 l/day to 52,000 l/day, directly connected to firing frames number reduction on fire configuration, draft control and baking optimization.

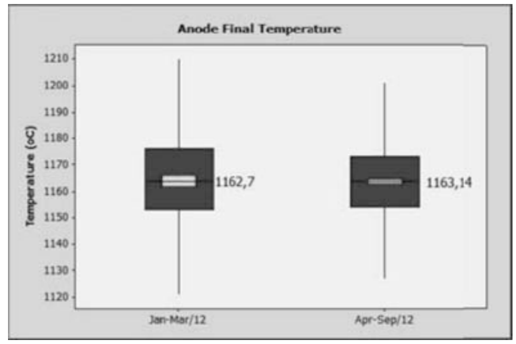

Figure 6 Final anode temperatures

Looking to quality aspects, Anode Baking Furnace uses Final Pit Temperatures measurement as an indicator of anode quality. Figure 6 compares the temperature distribution before and after all changes described above. Box-Plot chart shows no difference between temperatures measured. A good point is the lower variability of total data after the proposed changes on process parameters.

Other key parameters to evaluate the quality of the baked anodes are the baked properties. Figures from 7 to 12 show the comparison between key-properties of baked anodes.

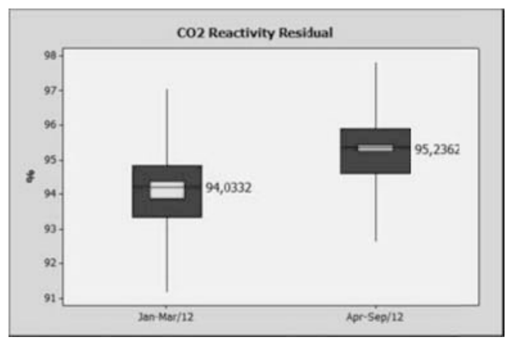

Figure 7 CO_2 Reactivity Residual

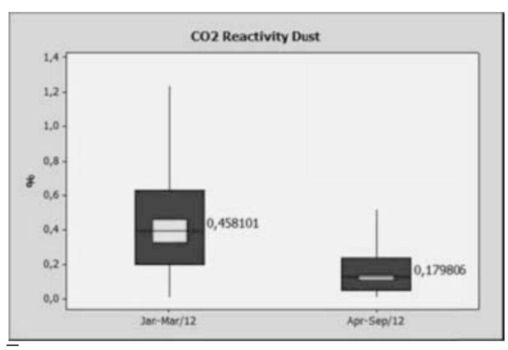

Figure 8 CO_2 Reactivity dust

The reactivities above are related to how well baked is the anode and to anode contaminants. Figures 7 and 8 show the improvement of the properties, even with lower temperatures and less baking time, CO_2 reactivities are better than before.

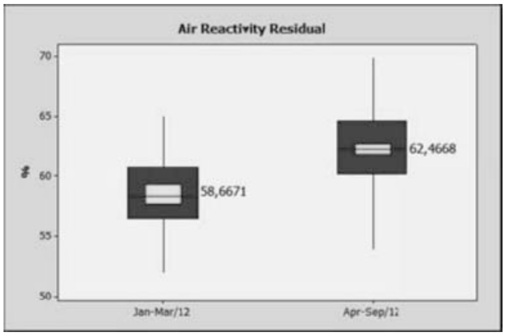

Figure 9 Air Reactivity Residual

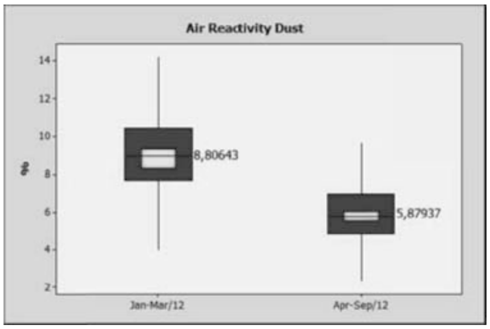

Figure 10 Air Reactivity Dust

Going in the same way as CO_2 reactivities, the Air reactivities were improved too (Figure 9 and Figure 10). All properties showed above are directly related to green anode formulation and contaminants, but the charts illustrate that baking process did not impact the results negatively. So, the reduced fuel consumption and lower final anode temperatures guide to better energy efficiency, maintaining the anode quality.

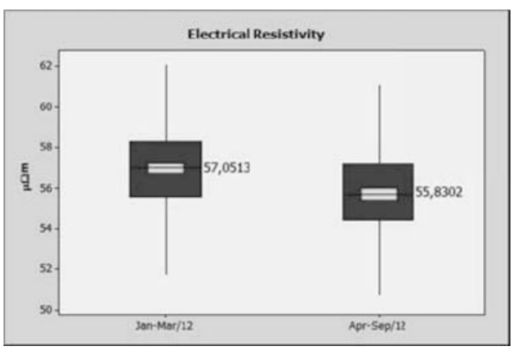

Figure 11 Electrical Resistivity

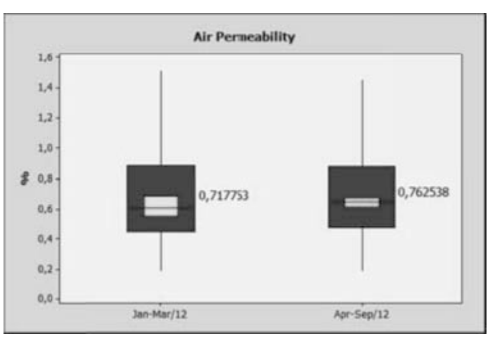

Figure 12 Air Permeability

The two last charts are directly related to the baking process, more exactly to the pre-heating evolution, when pitch tar fumes are volatilized and burned inside flues. During this step, it is really important to control the anode heat-up rate, avoiding cracks and high permeability. Figure 11 shows the improvement in Electrical Resistivity after pre-heating control implementation on the Furnaces. Looking to Figure 12, the Air Permeability had no significant changes after the changes described above in this paper.

Conclusion

The above results about parameters changes demonstrate improvements to the Anode Baking Furnaces operation. Technology, Maintenance, Refractories and Operational teams developed a team-work that allowed the execution of expressive changes and the achievement of fantastic levels as showed on Figure 5.

All the properties showed on Figures 7 to 12 can illustrate the gains in Energy Efficiency without negative impacts to baked anode quality. Once Green Mill improved anode formulation and contamination levels, the baking process did not cause any loss to reactivities, and the proper control of pre-heating promoted the improvements to electrical resistivity, maintaining the air permeability at the same level.

The development of a manual device to control draft was the first step to begin all tests and changes, enabling the pre-heating control and baking parameters optimization. Maintenance team worked to implement this improvement, allowing the operational crew to control pre-heating evolution properly, reducing heat-loss by exhaust manifolds and fuel consumption to supply the lost volatiles due to the high draft. Refractory team did its work, keeping sealing parameters under control and executing the rebuilding of critical sections and replacement of the critical flues, avoiding cold air inlets and renewing furnaces refractories to proper Fire control.

After the pre-heating zone was controlled, the Technology Team worked to develop new temperature curves, optimizing the baking curves, reducing fuel consumption and improving energy efficiency of the process. The reduction in baking time and firing frames number were the main enabler to the expressive fuel savings. All of that were possible due to operational crew exceptional work on the new practices, improving their knowledge about firing technique. Operators developed new operational routines to supply the needs of new process parameters and practices.

References

1. Keller, F and Sulger, P O. Anode Baking: Baking of Anodes for the Aluminum Industry. R&D Carbon Ltd. 2nd Edition, 2008. Sierre, Switzerland.