

REFURBISHMENT AND MODERNIZATION OF EXISTING ANODE BAKING FURNACES

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Abstract

Deformation of the flue and head walls lead among others to inhomogeneous baking of the anodes and consequently to a deterioration of the resulting anode quality. The aging of the baking furnace gets critical when the inferior anode quality impacts the current efficiency in the pots and hence boosts the aluminum production cost. A refurbishment with modernization of the anode baking furnace is then justified.

This paper outlines different scenarios and provides an optimum strategy for a refurbishment of the anode baking furnace. The different working steps, measures to minimize the anode production loss during project execution and criteria for furnace modernization are described.

Introduction

As shown below in figure 1, anode quality has a very high impact on carbon gross consumption and consequently on the aluminum production cost. Therefore, in order to reduce smelter costs, production of anodes has to aim quality and process consistency, i.e. better performance in the pots.

The theoretical consumption is given by the stoichiometric equation according to the Faraday law. To produce 1 ton of aluminum, 334 kg of carbon are needed, assuming a current efficiency of 100 %:

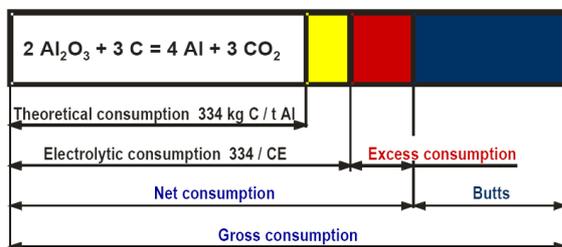


Figure 1 – Anode consumption as quantification of anode performance kinetics (Source: Meier, Fischer, Müller “Influence of Anode Quality on Aluminum Production Cost”)

Baking process

Baking represents the most expensive step in the production of anodes for the aluminum industry. It has

been observed that, in a considerably number of aluminum smelters improvement potential in anode baking process is proportionally also very significant.

Mainly following properties shall be taken into consideration when analyzing the impact of baking process on the overall quality of the anode:

- CO₂ reactivity
- Air permeability
- Thermal conductivity
- Air reactivity
- Mechanical strength

Physical condition of the baking furnace as well as process related parameters have a direct influence on aforesaid properties and hence an important impact on the performance of the anode in the pots.

In connection to the baking furnace, its ancillary equipment and the necessity and criteria to be considered for scheduling a refurbishment, some aspects have to be considered:

Brickwork aging:

- Maintenance cost and efforts: drastic increase of flue wall repair and replacement frequency;
- Loading factor: reduction of pit setting weight due to serious deformation of flue walls;
- Baking scrap: increase of anode rejection rate, mainly because of air burnout (cracks and fissures in the flue walls);
- Temperature distribution: decrease of pit temperature homogeneity leading to impoverishment of anode quality, increasing carbon gross consumption and hence aluminum production cost;
- Energy consumption: damages and deformation of brickwork will produce excess of required flue gas flow. Additionally decrease of baking efficiency will require extension of cycle time, implying in higher energy consumption.

Operation:

- Anode dimensions and pit usage: changing of pot design and anode size have a major impact on the anode loading arrangement in a pit. Ratio between volume of anodes and packing coke in a pit, should not be less than 60%;
- Production figures: higher anode demand may require increase of baking output.

Refurbishment with modernization – common scenarios

The table shown in figure 2 below, illustrates the different scenarios and appropriate measures to be considered in the refurbishment process.

The scenarios described are not mutually exclusive, however to overcome a problem solely related to an increase of maintenance, loading factor or baking scrap, all related to physical damages/deformations of the brickwork, undertaken of a flue wall and/or head wall repair/renewing program should demonstrate to be sufficient. In this stage the introduction of an optimized flue wall design (obtained with flow modeling) obviously contributes in process and anode quality enhancement.

	Brickwork				Process & ancillary equipment	
	Flue wall replacement	Head wall replacement	Height increase	Change of pit dimensions	Auto firing system	Fume treatment plant
Maintenance	■	■				
Loading factor	■	■				
Baking scrap	■	■				
Temperature distribution				■		
Energy consumption	■	■			■	
Pit usage	■	■	■	■		
Production requirement	■	■	■	■	■	■

Figure 2 – Scenarios and strategies in the baking furnace refurbishment process

In a further step, it has been demonstrated that modern designed Auto Firing Systems (AFS), are indispensable to achieve temperature homogeneity and reduction of energy consumption. In general the right choice of the AFS and an optimized flue wall design are intrinsically linked and hence condition sine qua non for a good and homogeneous temperature distribution in the pit.

Non optimal pit usage can only be corrected by changing pit dimensions according to anode size. This is usually performed with a complete re-engineering of the furnace, customizing flue wall length and pit depth. Due to the extension of this measure, higher capital expenditure together with production losses during work execution shall be considered. Despite of the higher investment required, benefit of improved pit usage and consequent production gains, energy savings and anode quality increase are widely compensatory. An example is shown below, figure 3. Following assumptions based on a case study presented by Meier at the “Iranian Aluminium Industry Congress”, 2004, were made:

- initial investment of approx. US\$ 20 Mio for refurbishment and modernization of a baking furnace and ancillary equipment for a production of 138 000 MT/a of anodes (i.e. 300 000 MT/a of aluminum);
- Yearly savings with brickwork maintenance: reduction of approx. 10 Kg of refractory for each MT of produced anode (from approx. 15 Kg/MT to an average of 5 Kg/MT);
- Cash inflows with reduced anode cost: benefits due to improvement of anode quality decreasing anode net consumption by 30 Kg/tAl (from 460 to 430 Kg/tAl) representing savings of approx. US\$ 3 600 000;

- Cost of money: 10%/a.

In this particular case, positive NPV is obtained after 5 years showing that investment in this project is the right decision. This is just a very simplified consideration of the economics related to a specific project. More realistic and complex calculations should include other factors, e.g. taxes, uneven cash flows, external variables and salvage rules. The intention of this calculation is to exemplify and demonstrate the significant cost impact of anode quality improvement and the fast return of related investment.

Initial investment:	\$ 20.000.000
Operational savings:	-\$ 1.184.040
Incoming cash flow:	\$ 3.600.000
Cost of money:	10%

Years		NPV
0	-20.000.000	-20.000.000
1	4.349.127	-15.650.873
2	3.953.752	-11.697.121
3	3.594.320	-8.102.801
4	3.267.564	-4.835.237
5	2.970.512	-1.864.724
6	2.700.466	835.741
7	2.454.969	3.290.710
8	2.231.790	5.522.500
9	2.028.900	7.551.400
10	1.844.455	9.395.855

Figure 3 – Sample NPV calculation.

Figure 4 below shows a typical example of an existing furnace with a very low pit usage factor (“present configuration”).

This is normally a consequence of continuous change of the anode dimensions without corresponding adaptation of the furnace and pit layout.

The excess of packing material produces higher coke and energy consumption (poor thermal efficiency). Additionally anode quality and production figures are extremely compromised. In this particular case, pit dimensions have to be modified an furnace configuration adapted.

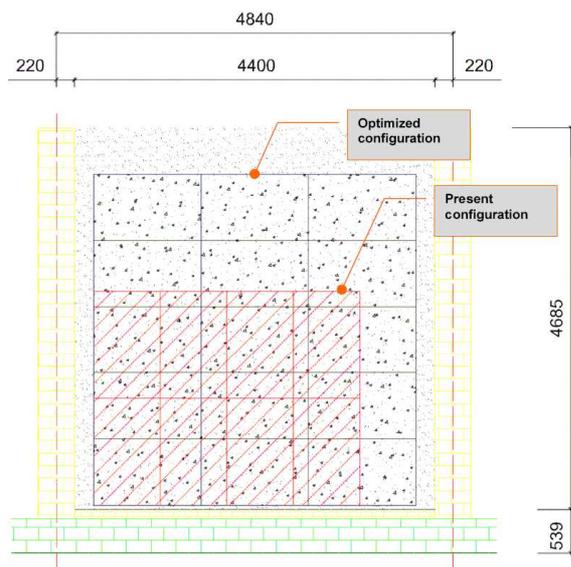


Figure 4 – Present and optimized pit usage.

Since pit and section dimensions must be changed, flue gases ring main has to be replaced (new risers arrangement). In addition, crane and conveyors must be adapted accordingly.

Figure 5 shows the relation between pit setting weight and fire cycle.

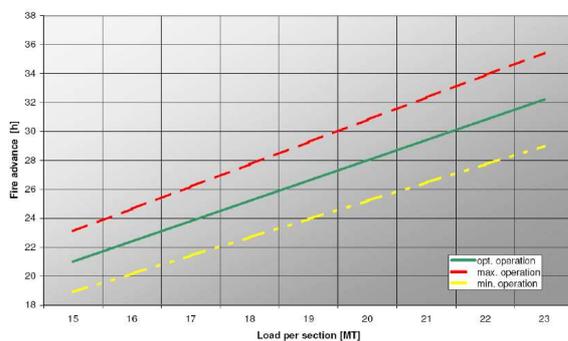


Figure 5 – Relation between pit setting weight and fire cycle.

It is important to be observed that in order to obtain required production figures with a good anode quality, the fire cycle should be located in a given range. This range is a direct function of the actual setting weight. Overstressing baking curves will invariably lead to impoverishment of the anode quality.

To fulfill additional or growing production requirements, furnace modifications including redesign of pit dimensions as well as increase of total number of sections (furnace extension) and fire group configuration are usually necessary. This includes among others:

- Optimized pit design: pit length and depth are customized in order to offer best possible pit usage with a given anode size. As mentioned before, volume ratio between loaded anodes and packing material shouldn't be lower than 60%. To achieve outstanding anode quality and improve process

parameters, flue walls should incorporate latest and best available design;

- Brickwork engineering: utilization of refractory and insulation materials of high quality standards increases thermal efficiency and extends furnace lifetime. The furnace design is also of fundamental importance to achieve satisfactory results in baking performance and brickwork lifetime;
- Modification of ring main: in order to fit new section dimensions (position or risers), ring main has to be completely changed/renewed.
- Concrete tub and foundation: the goal is to maintain tub, foundation and furnace building as far as possible untouched. The reason is obviously to reduce investment cost and justify return of investment (ROI). Application of modern furnace design & engineering together with advanced material technology solutions have shown very effective. In the majority of the cases, existing tub and infra-structure could be maintained without compromising achieved results.
- The introduction of modern and efficient AFS's together with a new fire group configuration, is one of the main keys and essential equipment to reach high production capacities with outstanding anode quality and energy figures, without impairment of brickwork or reduction of lifetime.
- Due to increase of pit setting weight and overall production figures, the fume treatment plant has to be reviewed and eventually replaced by a unit with higher capacity. The selection and design of the fume treatment scrubbing system has to take into consideration furnace and production parameters as well as environmental regulations in force. Conventional systems based on alumina scrubbing have been widely used in the aluminum industry. Due to recent and more strict environmental regulations and the relatively limited efficiency of those "conventional" systems in depuration of benzene and PAH's (carcinogenic substances), new as well as modernized baking facilities have been equipped with systems based on RTO's – regenerative thermal oxidizers. In a system based on RTO, VOC's (volatile organic compounds) of the furnace off gases are burned reducing the total organic carbon (TOC) emissions to a minimum (usually less than 20 mg/Nm³) fulfilling completely latest environmental regulations in force. In this concept, an extra module to scrub HF (fluoride) compounds must eventually be considered. This HF filtering system can be based on alumina or calcium carbonate ("limestone", CaCO₃) scrubbing units. In case HF is not an issue, baking furnaces can be operated utilizing only a RTO unit.
- Modifications/adaptations of the anode handling system – cranes and conveyors, shall also be considered. Refurbished and modernized furnaces will in general demand handling of significant higher number and tonnage of anodes. Overhead cranes designed 20 or 30 years back do not cover the new production and handling requirements and must also be refurbished or even replaced. As explained before, in order to accommodate anodes with bigger sizes, furnaces must generally be extended in height leading to reduction of available clearance between resulting operating

floor and crane lowest point. That mostly leads to problems related to motion and safety issues: crane can collide with furnace equipment and/or make operations unsafe for furnace operators. To overcome this problem “flat” overhead cranes with specially designed anode handling and loading/unloading devices are utilized.

Strategy

The decision of <<when>> and at how extend a refurbishment must be undertaken should take into consideration the factors mentioned before as well as capital expenditure and operational aspects.

It is clear that the benefits obtained with an optimization of the baking process, expressed into NPV and/or ROI justify the decision of scheduling an intervention. The extend of the work and scope depends on available resources as well as weight and significance of benefits obtained in the overall smelter account.

One more aspect to be considered is of logistic nature. Smelters with exhausted anode production capacity and consequential restricted or inexistent anode inventory flexibility are commonly forced to buy anodes for the period of refurbishment. This very onerous extra expense has also to be considered in the project planning.

Conclusion

Baking cost and anode quality are of vital importance in the aluminum production the smelter running costs.

Existing baking furnaces with low efficiency and advanced aging can be refurbished and modernized to an extend to fit benchmarking production figures – anode quality, energy consumption, OPEX and environmental aspects.

Those issues along with obtained results are the driving forces of recent developments undertaken in order to serve specific and extensive requirements of the aluminum industry related to the adaptation of baking facilities.

References

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