3D Transient Modelling of a Complete Fire Line for Anode Baking Furnace Design and Optimization

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Abstract

Computational Fluid Dynamics models have been a precious tool to support the evolution of the Anode Baking Furnace (ABF) designs over the last 20 years. Those models were mainly focusing on the air flow repartition within one fluewall in order to guarantee a good anode baking homogeneity and an efficient combustion. The combustion of the volatile matters and the fuel were usually not taken into account. A new 3D transient model was developed for a complete fire line (preheating/heating/cooling). This model combines the air flow characteristics (distribution, air ingresses/exfiltrations) with the combustion of gas and volatile matters and the heat transfers through the materials. The model results have been compared with measurement done on different furnaces with excellent outcome. It is a powerful tool to better understand the impact of different parameters, and therefore improve furnace design and performance and anode quality. For instance, it is used for modification of existing ABFs to support pot amperage creepings: implementation of higher fluewalls for longer anodes, narrower fluewalls for higher anodes, and shorter time cycle for higher production. In this article, the model will be described and some applications will be discussed.

Keywords: Anode baking furnace, combustion, heat transfer, anode temperature homogeneity.

1. Introduction

The Anode Baking Furnace (ABF) dimensions for new projects tend to increase with the increase in anode dimensions and smelters productivity. In parallel, many furnaces have evolved in the last years in the frame of smelter creeping projects, with the same objective to increase furnace productivity: shorter time cycles, increase of anode height with narrower fluewalls, increase of anode length with furnace raising, change of loading configuration, etc.
The process, design and geometrical changes that are needed to answer to those evolutions have a direct impact on anode quality and furnace performance, which are complex to anticipate.
Unanticipated changes in pitch combustion efficiency or anode final temperature for example can have a deleterious impact on the anodes behavior in the potline (anode reactivity, anode dusting) as well as on the furnace performance (higher gas consumption, incomplete combustion, soot deposits).
Due to the relatively long and complex process of baking the anodes, the trials on ABF to evaluate the impact of those changes are usually time consuming and costly. It is also not always possible to easily test a change in furnace dimensions or design.
Therefore the computational models are valuable tools to support design and process optimization. With the evolution of modeling technologies and computational resources, the models are allowed to become more and more complex to better reflect the process [1 to 4].
Those models have become an essential tool to support production increase in the frame of creeping projects, or to develop the furnace design for a more robust process. They allow the anticipation of process changes in order to decrease project risks and are a reliable tool to compare different technical solutions.

2. Model description

2.1. General presentation

The model is a 3D-transient model describing a full line of fire, from the preheating to the cooling.
The calculations are done on a half - fluewall and a half - pit due to the symmetries of a fire line.
The Figure 1 shows a general view of a fire with the cooling sections in the foreground and the preheating sections in the background: the demarcated red area represents the extraction of the geometry done in the model. The fire line includes all the sections from preheating to blowing. Depending on the desired outcome of the model, the fire line might also include the cooling sections (red doted area in Figure 1).
If the furnace uses a 4^{th} heating ramp during a portion of the cycle, each cycle can be split in two to represent the baking extension and the time when only three ramps are running.
The model combines different phenomena occurring during the baking of anodes, such as:

- Releasing and combustion of anode volatile matters in the preheating zone,
- Combustion of the natural gas in the heating zone,
- Air flow through the fire,
- Heat losses,
- Air infiltration and exfiltration,
- Air flow repartition through each fluewall.

The calculations are done with Ansys® softwares, and more precisely with Fluent® for the calculation of flow repartition and heat transfers.

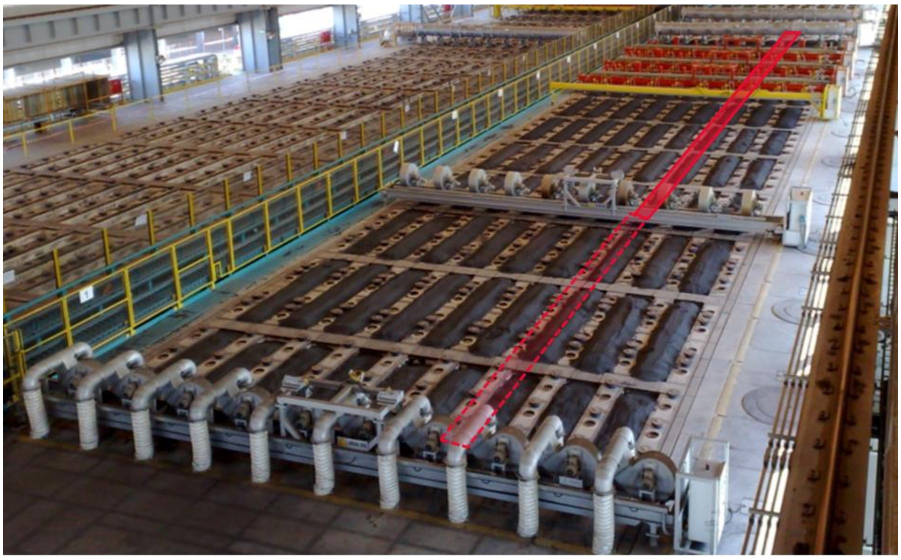

Figure 1. General view of an open Anode Baking Furnace and representation of the fire geometry used in the model.

2.2. Model inputs

The inputs of the model are the following:

- Fluewall, packing coke and anodes geometry (including the position of the tie bricks and baffles, but excluding the isolation bricks),
- Air and fumes flow through the fire line,
- Gas flow through each injector in the heating sections,
- Quantity of pitch available in the anodes for the combustion of volatile matters,
- Material properties for bricks, anode, packing coke and top blocs.

4. Conclusion and perspectives

The model has been developed and has shown excellent correlation with the data measured on two existing furnaces. With these promising results, the model is now used to support several projects both internally and for external customers:

- Comparison of fluewall designs (for example design with or without baffles in the context of fluewall width reduction),
- Study of the impact of fluewall height increase on the baking homogeneity,
- Optimization of existing designs for a better baking homogeneity,
- Study of the impact of different operating parameters (gas pressure, injection depth, time cycle),
- Optimization of the cooling efficiency (cooling configuration, cooling ramp power)

In parallel, the model is further developed to maximise the potential of this tool. The on-going and future developments include:

- Control of the quantity of injected gas with a PID adjustment loop based on a curve of temperature set points measured in peephole 4 of each heating section (instead of being an input value),
- Control of the air flow with a PID adjustment loop based on a curve of temperature set points,
- Further development of the model with pulses to better understand the impact of burner design and parameters on flame length, NOx formation, combustion efficiency,
- Thermomechanical stresses and constraints for the refractory depending on the operating conditions and furnace design,
- Correlation between temperature profile and baking level in Lc to have a direct view on the baking level homogeneity depending on the profile of temperature that each point has seen.

This model is a leading-edge tool that allows for the optimization of ABF's design and performance, whether new or already in-use.

5. References

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