Effects of Flue Wall Deformation on Aluminum Anode Baking Homogeneity and Temperature Distribution

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Abstract

The quality of anodes used in aluminum industry depends strongly on the baking process. It is essential to achieve a uniform temperature inside the anode during the baking process. Flue wall may deform during the service life of the furnace that may affects the baking process of the anodes and consequently reduce the quality of the anode. During furnace operation, the thermal expansion of flue walls is restrained due to the presence of headwalls that may promotes the deflection of flue walls. This study aims at investigating this phenomenon by developing a 3D model able to take into account a large number of physical phenomena and parameters that play a role in the baking process and affect the flue wall deformation process. This 3D model takes into account the thermo-hydro-mechanical coupling due to coupled fluid flow and transient heat transfer, packing coke load and the thermal expansion, the model is used to analyze the influence of these parameters on the resistance and deflection of the flue walls. This model can be used as a useful tool to study the effect of flue wall deflection on the aging of carbon anode furnaces.

Keywords: Baking process; aging; deflection; flue wall; thermo-hydro-mechanical coupling.

1. Introduction

The anode baking is the most expensive step in anode production. Fuel and refractory maintenance represent approximately 15% of total anode manufacturing cost. The baking of the anode is completed in an anode ring furnace. Such furnaces are composed of a number of sections with the anodes placed between flue walls into the pit. The firing zone is moving and the anodes remain stationary. Figure 1 shows a typical view of an open top furnace and a three-dimensional view of one section of the ring furnace. The whole furnace is made of a few such sections, forming an oval-shaped ring. Each section is divided into several pits with anodes stacked in each pit. In an aluminum type furnace, anodes are stacked in three layers. The pits are separated by pit walls, in which the hot gases flow. Approximately 100 anodes are loaded in each section. The anodes are surrounded by packing coke, which gives physical support and acts as a heat transfer medium. In the preheating and heating section, hot gases in the wall flues for transmission of heat through the brickwork and packing of coke to the anodes. In the cooling section, ambient air is used for cooling the anodes in a similar way. At the front of the fire, a chain of ring furnace sections operating in different parts of the baking cycle and linked together as a series of batch processes with a common gas flow between them, a draught fan maintains the gas flow through the chain of sections. Inflowing ambient air enters the last section in the fire train and is preheated by cooling the anodes. The heated air supplies oxygen for the combustion of oil in the heating sections. In the preheating sections, cold anodes are heated by hot gas and combustion of hydrocarbon volatiles coming from the binder pitch. Thus, the heat comes from combustion of liquid or gaseous fuel as well as from hydrocarbon volatiles coming from the binder pitch. Thus, the heat comes from combustion of liquid or gaseous fuel as well as from the hydrocarbon volatiles, mainly tar, methane and hydrogen. Some heat also comes from combustion of the packing coke covering the anodes.

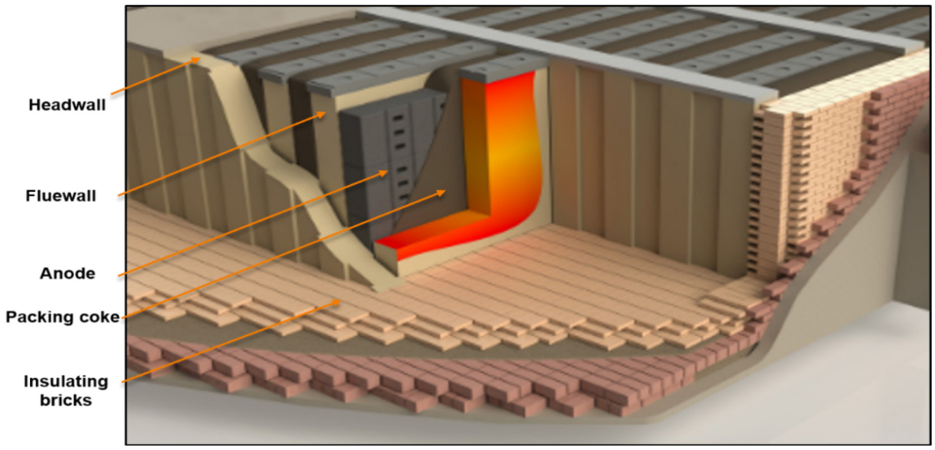

Figure 1. General overview of a typical anode baking furnace[1]

The quality of the anode used in the aluminum industry depends strongly on the baking process. In general, it is desirable to achieve a more uniform temperature inside the anode during the heating process. The aging of the baking furnace and the 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[2, 3]. The development of a three-dimensional (3D) computational model able to take into account a large number of physical phenomena and parameters that play a role in the baking process and affect the flue wall aging process is needed.

Due to the huge dimension of the furnace and its very large time constant (in the order of months), it is not always possible to conduct physical experiments in order to determine the influence of the flue wall deformation on furnace's behavior and efficiency. The increasing interest in this topic has heightened the need for a mathematical model as a tool for predicting the influence of the flue wall aging on the anode baking homogeneity. However, few recent investigation studies have focused on the flue wall deformation modes, and how this deformation can affect the quality of the baked anodes [4, 5], the research has tended to focus on the process modeling considering a straight flue wall, and less attention has been paid to how the degree deformation of the baking furnace can affect the baking process efficiency.

In this study, we developed a 3D model that take into account the thermo-hydro-mechanical coupling due to coupled fluid flow, heat transfer and flue wall deformation. The fully coupled thermo-hydro-mechanical simulations were done by the finite element multi-physics commercial software COMSOL. Such 3D multi-physics modelling can be used as a powerful tool in the prediction of the effect of the flue wall deformation on the anode temperature distribution and homogeneity and thus predicting the anode baking quality. The present study gives useful insights for temperature distribution adjustment as a function of the flue wall and furnace design.

The life of carbon baking furnaces is usually limited by the deflection of its flue walls. This deflection as showed in Figure 2-a is promoted principally by the action of the headwalls which restrain the free thermal expansion of the flue walls, and by the action of the packing coke whose weight is partially supported by the flue walls. The resistance to deflection of the flue walls is a function of their rigidity [6]. In an open carbon baking furnace, the flue walls consist of firebricks linked together by mortar in horizontal joints. During service, the thermal expansion of flue walls consist of firebricks which are usually linked together by mortar. During homogeneity, in order to establish a flue wall deformation modes database linked to the consequence on the anode baking quality

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5. References

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