Effect of Mechanical Stress on Pitch Distribution during Anode Baking

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Abstract

The baking process is a critical step in carbon anode production, during which significant microstructural evolutions take place in anodes. Anode sticking is one of the industrial challenges affecting anodes after baking. It refers to either anodes sticking together or packing coke adhering to the anode surface, resulting in increased anode losses and overall production costs. Since many anodes are vertically stacked together in the baking furnace, the mechanical stress generated by the weight of the top anodes may lead to viscous pitch squeezing out of the bottom anodes during baking, which is thought to enhance anode sticking. This work aimed to investigate the presence of pitch squeezing out of anodes by studying the influence of uniaxial compressive stress on pitch distribution. A marker was added to the pitch so that the pitch distribution could be monitored by elemental mapping using XRF spectrometry. Pitch marker development was performed by choosing three oxides (ZnO, FeO, Bi_2O_3) and using different mixing procedures. Lab-scale anodes were then fabricated with an optimized pitch ratio having 1 wt.% Bi_2O_3 as a chosen marker. Green anodes were subsequently baked under uniaxial compressive stresses of 0 kPa, 25 kPa, and 50 kPa, corresponding to the stresses exerted on the top, middle, and bottom anodes in the industrial furnace, respectively. The results indicated that the mechanical stress impacted baked anode properties by decreasing electrical resistivity, although apparent density variation was not significant. XRF analysis revealed a considerable difference in Bi distribution between green and baked anodes. Significant pitch dispersion over baked anodes determined the pitch tendency to squeeze out of the anodes, which can be used to explain the anode sticking. Additionally, pitch marker application was revealed to be a suitable method to trace pitch distribution after baking to eventually correlate it with anode sticking issue.

Keywords: Carbon anode, Anode sticking, Packing coke, Pitch distribution, Mechanical stress.

1. Introduction

Carbon anode is an essential part of the primary aluminium production in the Hall-Héroult process as it conducts electrical current and acts as a reducing agent [1]. The anode is consumed during electrolysis and for producing one ton of Al, between 400 kg and 450 kg of the anode is consumed [2]. The anode is made by compacting and baking an anode paste. The anode paste is obtained by mixing two main constituents, i.e., calcined petroleum coke (CPC) as dry aggregate and coal-tar-pitch (CTP) as binder, to which recycled anode butts could also be added. The resultant anode paste is then compacted, forming a green anode which is subsequently baked at 1100 °C – 1200 °C. To prevent anode oxidation during baking in the furnace, packing coke is poured between the anode and the furnace refractory walls [1, 3]. During the heating cycle in the furnace, solid pitch changes to liquid phase at about 120 °C – 220 °C, releases volatiles and transforms to coke at higher temperatures [3, 4]. The released volatiles escape from the anode and if the rate of volatile generation exceeds the rate of its escape through the porous structure of the anode, it may create an internal pressure in the anode during baking [4]. The baking process is a critical step contributing to the desired physical, mechanical, and electrical properties in the resulting anode block.

It is frequently observed that the packing coke sticks on the anode surface (Figure 1). In some cases, even two anodes, piled over each other in the furnace, may stick together. These phenomena are known as “anode sticking”, which is an industrial challenge [5] since the stuck anodes require not only additional operator interventions for unloading the furnace after baking, but they also need serious safety considerations for being carried from the furnace to their next positions. Moreover, anode sticking leads to material loss due to discarding anodes in case of breakage or severe coke sticking [6, 7]. Stuck coke also fills anode slots, requiring anode slotting machines to regenerate them. Consequently, anode sticking results in a significant increase in overall production costs.

Figure 1. Sticking of packing coke to anode blocks (Courtesy of Alcoa Corporation).

Several investigations have been performed to identify the primary reasons leading to anode sticking. Most of them have revealed that overpitching greatly contributes to anode sticking owing to excessive released volatiles during baking [5, 6]. Besides, low Blaine Number of fine coke as well as low quantity of fineness at a constant pitch ratio have been demonstrated to cause anode sticking [5]. Meanwhile, anode sticking has also been attributed to compacting process conditions, including high forming pressure and severe vacuum usage [5, 8]. Despite these reported observations, no systematic study has been carried out to rationalize the effect of different parameters on anode sticking.

In industrial baking furnaces, three anodes are generally stacked on top of each other, generating mechanical stresses on the lower anodes [9]. Therefore, it is reasonable to hypothesize that liquid viscous pitch squeezes out of the anodes during baking, due to the stress induced by the weight of the top anodes and enhances the anode sticking phenomenon. The effect of this induced stress has also been reported on the electrical conductivity of the bottom anodes [9]. However, to the best of our knowledge, no study has examined the effect of the vertical position of the anodes (externally induced mechanical stress during baking) on the anode sticking. Therefore, the objective of this work was to determine the influence of uniaxial compressive stress on the flow of the pitch and to reveal if it is squeezed out of the anodes during baking. To reveal the pitch flow, the pitch distribution was tracked in the cross-section of the baked anode. Once the pitch squeezing is observed, it can be correlated with anode sticking in future studies. For the aim of this paper, an optimized pitch ratio was first determined for a certain type of coke and pitch. Then, a suitable pitch marker was used to be able to track pitch in the green and baked anodes. The pitch

6. References

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