An Experimental Testing of the SERMA Technology for the Quality Control of Green and Baked Anodes

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Abstract

It is well known that the quality of carbon anodes is important for the aluminum industry. Carbon anodes provide the necessary carbon for the reduction reaction in the Hall-Héroult process. An increase in their electrical resistance results in an increase in energy consumption and greenhouse gas emissions. It is thus important to have, at the disposal of the industry, a non-destructive tool to ensure their quality. Current practice uses visual inspection or destructive sampling methods, which offer limited information on the anode quality. In contrast, SERMA (Specific Electrical Resistance Measurement of Anodes) is a non-destructive method that uses the electrical resistivity distribution to determine the state and the integrity of the anode. This method, which can be implemented easily in a production line, allows the quality control of both green and baked anodes. The method used by SERMA has been validated on lab-scale anodes, and the results have been published previously. In this study, a prototype for industrial application has been built, and tests have been carried out on industrial green and baked anodes. In this article, the results of this study will be presented, which shows the ability of the method to detect both green and baked defective anodes.

Keywords: Carbon anodes, quality control, non-destructive method, electrical resistivity.

1. Introduction

An important part of the aluminum production cost pertains to carbon anodes, which includes the raw material and fabrication costs. Their poor performance in terms of energy and carbon consumption in the electrolysis cell could increase their contribution to the cost of production even further. Poor mechanical or chemical anode properties decrease the anode life due to breakage, thermal shock or increased air and CO_2 reactivities [1-3]. This, in turn, decreases the productivity. Thus, it is important to fabricate good quality anodes.

Three main steps of the anode production are paste formation, compaction, and baking. During the baking process, the release of volatiles from pitch, which is used as the binder, exerts pressure within the anode. This might cause the formation of cracks and defects in baked anode, which affects its final quality [1-3]. Therefore, it is important to control the anode quality before its introduction into an electrolysis cell. Two main quality control methods that are widely used in the industry are visual inspection and tests on cores from baked anodes. Visual inspection provides limited information on the anode quality based on only surface defects. In contrast, coring provides more, but limited information on the internal anode defects but only in a small region, usually close to the top part of the anode. This does not represent the entire anode quality. Moreover, coring is a destructive technique, which is applied to only a small number of anodes (about 1.5% of the anodes produced) [1].

There exists, however, some non-destructive techniques that are widely used in other fields. Among them, the ultrasound and the eddy current techniques have been applied for material inspection. Some researchers investigated the use of ultrasound inspection for carbon anodes. Amrani et al. [4, 5] applied this technique on core samples obtained from carbon anodes and was able to detect cracks on these samples. More recently, Ben Boubaker et al. [6] used the ultrasound inspection on thin slices taken from an industrial anode and analyzed the acoustic response using wavelet transforms. Then, they combined the signal and multivariable statistical analyses in order to determine the internal morphology of the anode samples. They validated their method comparing with the X-ray tomographic analysis of the same samples. Both works of Amrani et al. [4, 5] and of Ben Boubaker et al. [6] were carried out on small samples. To the best of authors' knowledge, currently there is no reported study, which demonstrates the possible application of ultrasound inspection on full size anodes due to the short penetration of the acoustic waves into the carbon material. Electrical resistivity measurement is another promising non-destructive technique for inspecting conductive materials. In general, it is based on the strong correlation between the local resistivity and the local density of a material. Variations in the resistivity values indicate variations in the state of the anode, reflecting possibly the presence of cracks or large pores in the material if the values are higher than normal. In addition, electrical resistivity is also related to anode reactivity since air and carbon dioxide can penetrate more easily into a porous structure, increasing the reactivity in the case of carbon anodes. These also affect other physical, thermal, and mechanical properties. Thus, electrical resistivity is a strong indicator of anode quality. This technique is employed in several fields [7-10]. For carbon anode inspection, the use of electrical resistivity has gained the interest of many researchers.

In a recent article of Rouget et al. [11], the use of Van der Pauw method is suggested to measure the resistivity and detect the flaws in a core sample. However, this is limited to a small sample and not applicable to a large anode block. Formerly, Seger [12] developed a system to measure the resistivity of a full size baked anode. In this system, the current enters the anode from the stub holes and leaves through a set of probes at the bottom. The voltage drop between the stub holes and the probe as well as the current flowing through each probe are measured. The electrical resistivity is then calculated from the values of the current and the voltage drop. Later, a similar system was proposed by Chollier-Bryn et al. [13] and by Leonard et al. [14] where they attempted to mimic the current distribution in an electrolysis cell. In this system, the current enters the anode from the stub holes and leaves from a metallic brush carpet at the bottom. The voltage drop is measured between a reference point at the top surface and a number of predefined points on the large side surfaces. The resistivity is determined by comparing the measured voltage drop to that obtained by a numerical model of a homogenous anode. Recently, Gagnon et al. [15] presented the results of the testing of this system in a plant environment.

The last two systems are only applicable to baked anodes. It would be helpful to control the quality of green anodes in order to reject defective ones as early as possible in the process and save the cost of unnecessary baking. Kocaefe et al. [16, 17] developed a technology, SERMA (Specific Electrical Resistance Measurement of Anodes), applicable to both green and baked anodes. SERMA is based on the measurement of electrical resistivities in two directions in the anode and the construction of a map of the anode's resistivity distribution. The analysis of the resistivity distribution permits the localization of internal defects. The experimental validation of SERMA using laboratory anodes was previously presented [18, 19]. Predefined defects were intentionally created in these anodes. The experiments showed that the resistivity values were correlated well with the anode porosity and the defects present in the anodes. In addition, a

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