Determination of the Pitch Level in Green Anode Using Image Analysis

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Abstract

The anode quality plays an important role in aluminum production. Utilization of good quality anodes decreases the carbon and power consumptions as well the greenhouse gas (GHG) emissions, and increases the production. One of the important factors affecting the anode quality is the percentage of pitch used and its distribution in the anode. The under-pitched or over-pitched anodes decrease the anode quality, hence cause problems during the production. Currently, the quality of anodes is evaluated either visually or by characterizing a small core taken from the top of the anode, which does not represent the whole anode. In addition, core characterization is done only for 1.5 to 2 % of the anodes produced. The objective of this study was to determine the distribution of pitch on the surface of green anodes by image analysis in order to detect if the pitch distribution is uniform and if they are under or over-pitched. An image analysis software was developed for this end using Visual Basic. To test the software, ten laboratory anodes with different percentages of pitch, particle size distribution, and vibro-compaction conditions were produced in the carbon laboratory of the Research chair on industrial materials (CHIMI) of the University of Quebec at Chicoutimi (UQAC). Their images were analyzed with the software developed. A validation of the software, based on chemical analysis, was also carried out. This involved the spectrophotometric analysis of the pitch content of samples taken from different parts of the anodes, which were identified as over-pitched or under-pitched by the image analysis software. The results were in agreement with the predictions obtained with the software showing that it can be used as a tool to determine the pitch level (over or underpitched) on anode surfaces.

Keywords: Aluminum production, Under-pitched anode, Over-pitched anode, Image analysis, Spectrophotometric pitch analysis.

1. Introduction

The prebaked carbon anodes act not only as a source of carbon, but also as an electrical conductor during the aluminum electrolysis. They represent around 15-20 % of the cost of producing aluminum. They are composed of petroleum coke, butts, recycled green and baked anodes (dry aggregate) and coal tar pitch (binder) [1]. The quality of the raw material and the parameters of the manufacturing process such as chemical composition, electrical conductivity, thermal shock resistance, homogeneity, and air and CO_2 reactivities have a significant impact on the anode properties. Therefore, the quality of raw materials affects the energy and carbon consumption, production cost, and greenhouse gas (GHG) emissions.

It is also well-known that the quantity and the distribution of pitch in an anode are two of the important parameters affecting the anode properties [2-3]. The over-pitching significantly increases the quantity of volatiles, thus the greenhouse gas (GHG) emissions. This also leads to an overload in the volatile burning systems, hence greatly increases the fire risk. The release of large quantities of volatiles also result in crack formation in anodes. On the other hand, under-pitched anodes are more porous (less dense). They have high electrical resistivity. Utilization of such anodes increases the energy and carbon consumption. The uneven distribution of the pitch leads to the generation of cracks in the anode during baking and causes variations in the consumption of anode during electrolysis. However, there is no technology that can be used in the plant for quickly estimating the pitch percentage and its distribution in the anodes. The quality control concerning the pitch level is based on a visual inspection (color and surface finish) by the operators. The aim of this study is to develop a method based on image analysis to determine the distribution and the level of pitch on the green anode surfaces.

Image analysis is a well-known technique used in various fields such as analysis of medical x-ray images [4], extraction of character chains from overlapping images of text and its background [5], correlation of variations in chemical analysis, process parameters and mechanical properties of microstructures in steel industry [6], characterization of porous structures of copper [7].

The image analysis is vastly used in the field of aluminum. Solymar et al. [8] studied the microstructure of bauxite by digital image analysis using a scanning electron microscope and a micro analyzer electron probe. Martinent-Catalot et al. [9] have developed a new method of analysis of digital color images to characterize and identify different types of alumina used by aluminum smelters. Swillo and Perzyk [10] analyzed the surface of primary aluminum after casting to detect the surface defects.

Image analysis is also used for anodes and its raw materials mostly using the optical or scanning electron microscopes. Rorvik et al. [11] characterized the components of a green anode and the porosity of coke particles using optical microscopy and digital image analysis. Tessier et al. [12] used image analysis to determine the composition of the anode cover material. Bowers et al. [13] developed an imaging technique to determine the porosity, shape, and size of the calcined coke. Adams et al. [14] conducted an image analysis study for pitch in anodes. The aim of this study was to determine whether semi-automatic image analysis could give the appropriate amount of pitch for a defined size distribution of coke particles. However, their method was only applicable to large particles. Saravanan and Society [15] have proposed a new algorithm to preserve contrasts, sharpness, shadow, and image structure. Bhattacharyay et al. [2] focused on the development of a technique that can be used to analyze the distribution and amount of pitch, coke, pores and cracks on the surface of a green anode. These studies were mostly carried out in the laboratory. To our knowledge, there is no reported study to investigate the entire surface of an anode. The present study focuses on image analysis technique to identify pitch distribution on the surface of a green anode in real time. To do this, an image analysis software using the Canny algorithm and the distribution of primary colors, red, green, and blue (RGB), was developed. In addition, the Gauss filter is used to cancel the noise generated by the Canny algorithm. The software can determine if the surface of the anode is over-pitched or under-pitched. It can also determine if the pitch distribution on the anode surface is homogeneous or not.

The laboratory anodes with properties similar to those of the industrial anodes can be produced in the laboratory of Chair CHIMI at UQAC. Therefore, the method was first tested and validated in this laboratory. Then, it is tested in the plant with industrial anodes. This article presents the results obtained with the laboratory pilot anodes.

comparable. The higher the spectrometer reading is, the higher the percentage of pink (over-pitched) regions is. Similar results were obtained for all the anodes. These results show that the over-pitched regions can be identified with the image analysis software.

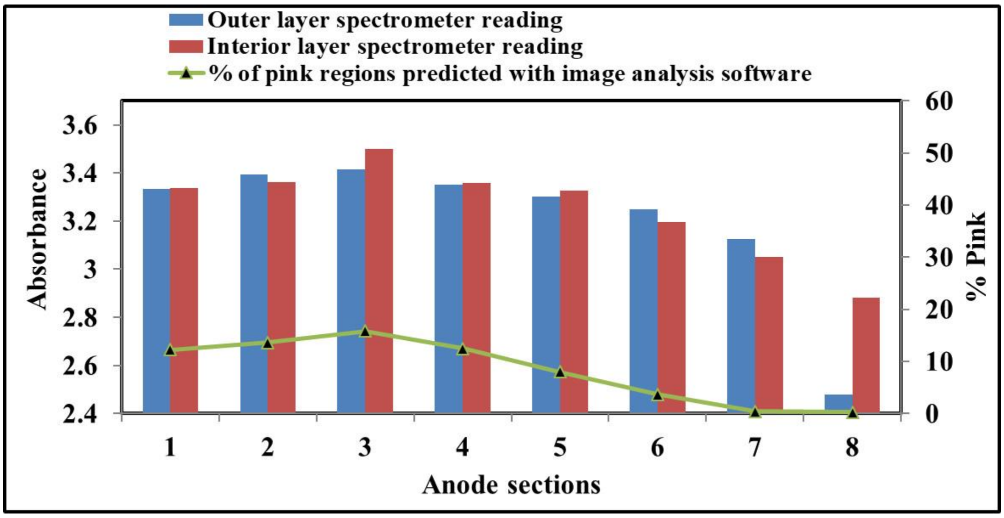

Figure 13. Spectral readings for pitch and image software predictions of pitch percentage (pink regions) for different sections of anode 1.

5. Conclusions

A simple system consisting of a camera and a light source was constructed to illuminate the anode surface. The developed image analysis software can quickly analyze the distribution of pitch on the surface of green anodes. It also determines whether the anode surface is over-pitched or under-pitched.

As it is well-known, it is difficult to predict the overall quality of the anode only from the conditions of its surfaces. However, the surface conditions are inspected by the operators, and the interpretation of each operator might be different. This software is meant to automatize the evaluation of the anode surface and eliminate the human error. It seems to be working well. The regions identified as over-pitched by the image analysis software on all the anodes were analyzed with spectrophotometry and the results confirm the predictions of the software.

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