Crack detection method applied to 3D computed tomography images of baked carbon anode

Donald Picard[1], Julien Lauzon-Gauthier[2], Carl Duchesne[3], Houshang Alamdari[4], Mario Fafard[5], Donald Ziegler[6]

1. Research Engineer,
2. PhD Student,
3. Professor,
4. Professor,
5. Professor,

NSERC/Alcoa Industrial Research Chair MACE3 and Aluminium Research Centre – REGAL
Université Laval, Québec, QC, Canada

6. Program Manager – Modeling, Alcoa Primary Metals, Alcoa Technical Center, PA, USA

Corresponding author: Donald.Picard@gci.ulaval.ca

Abstract

Carbon anodes used in the aluminium industry have been investigated through destructive and non-destructive testing (NDT). In the latter case, computed tomography (CT) has been previously used to map the 3D apparent density distribution and is now extended to crack detection. Previous work has shown how to overcome technical hurdles related with crack detection by using percolation based algorithms operating on low resolution images of full-scale baked carbon anode. The previous application to 2D images is extended here to the 3D case. The crack detection algorithm has been performed on two inch thick anode slices containing several independent macro cracks. The influence of the cracks on other NDT techniques is also highlighted.

Keywords: Carbon anodes, computed tomography, crack detection, percolation algorithm.

1. General

Of all materials used in the electrolysis cell, only carbon anodes (approximately 30 anodes per cell) could be considered as consumable items requiring regular replacement. These anodes are consumed during electrolysis and replaced after approximately 26 days of operation. Depending of the cell technology, approximately one anode per cell is replaced each day. Hence a large number of anodes and consequently a large quantity of raw materials are required to operate a plant. Also, to stay economically competitive and considering the large amount of anodes consumed each year, aluminium producers need to reduce the cost of their anode production. Part of the solution is to reduce the cost of the raw materials. The drawback is that producers now have to deal with continuous changing of raw materials properties, resulting in a wide variation of physical properties of the baked anodes.

One solution to minimize the effect of the variation of raw materials properties is to use numerical simulation methods to model the manufacturing process and/or to increasing the process control. The objective is to predict the anode characteristics, to control the process parameters more efficiently and to take corrective actions before the anode is produced. To achieve this goal, a series of experimental data must be first collected in order to validate the models. From a density point of view, the most efficient way to get 3D information is through the use of computed tomography (CT). Non-destructive anode investigation had thus three main objectives: 1) to obtain the apparent density distribution, 2) to estimate the porosity distribution and 3) to quantify the larger cracks inside the anodes [1]. The anode density mapping has already been addressed in previous studies [2, 3]. Hence, this paper focuses only on the quantification of large cracks in 3D.

1.1. X-ray computed tomography

Carbon anode images have been obtained by scanning a whole baked anode block using computed tomography (3D NDT imaging tool). The block investigated in this paper is the same one used in previous NDT studies [2-4]. The CT method has mainly one advantage that overcomes two disadvantages. The advantage is the nature of the technique itself, i.e. it is a non-destructive technique that does not involve the damaging or destruction of the sample and thus preserves crack integrity within the object. On the other hand, the scanning area of the X-ray apparatus (Siemens Somatom Sensation 64) was designed for the human body and consequently was too small for the anode (Figure 1). The block was thus sliced in 52 pieces of 50 mm thick [4] as illustrated in Figure 2. Also, to avoid excessive data, image resolution had to be adapted to the object size [4] resulting in a voxel (volumetric pixel) resolution of $0.7 \times 0.6 \times 0.7$ mm^3 (the thickness of voxels is 0.7 mm). Assuming this resolution, a typical anode slice will contain approximately $70 \times 468 \times 1068$ voxels (□ 35M voxels). Therefore, contrast between cracks and background (carbon) is reduced.

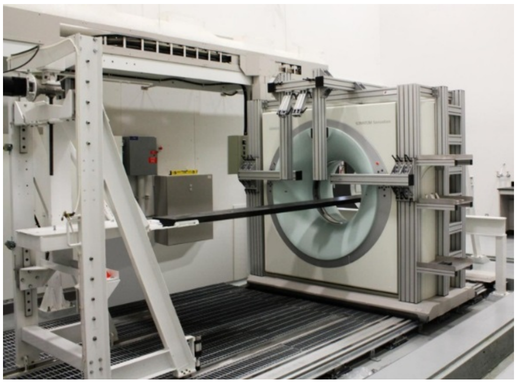

Figure 1 Siemens Somatom Sensation 64. Courtesy of INRS-ETE.

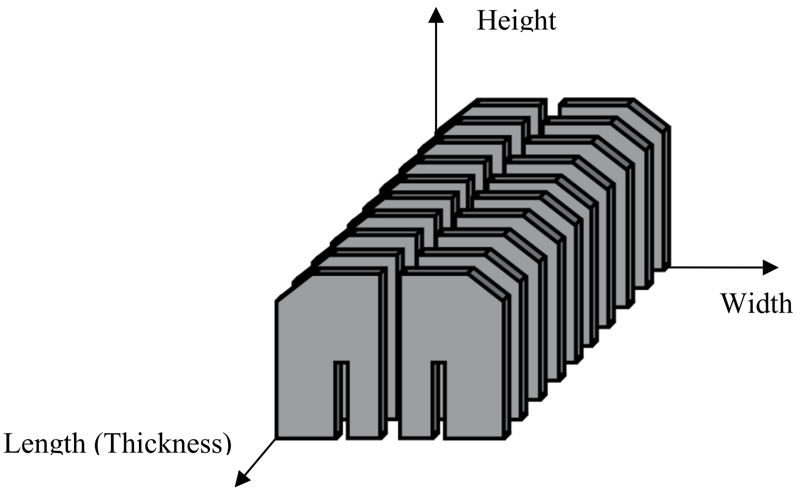

Figure 2 Scheme of the investigated anode slice pattern.

testing the algorithm on different CT scan resolutions and sample sizes as well as optimizing the processing time.

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5. References

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