

NEW METHOD FOR REPRESENTATIVE MEASUREMENT OF ANODE ELECTRICAL RESISTANCE

M. J. Chollier-Brym¹, D. Laroche¹, A. Alexandre¹, M. Landry¹, C. Simard¹, L. Simard¹, D. Ringuette¹
¹Rio Tinto Alcan, Arvida Research and Development Centre, 1955, Mellon Boulevard, Jonquière (Québec), G7S 4K8, Canada

Keywords: carbon resistivity, anode resistance, anode voltage drop, anode quality

Abstract

Anode electrical resistance is more and more recognized as a key parameter for pot operation, as the carbon material itself contributes close to 50% of the anode assembly voltage drop. Factors such as raw materials, forming and baking conditions are sources of significant variation in anode properties, including anode resistance. Anode resistance will vary within an anode and between anode batches, causing voltage differences up to several tens of millivolts. The current method for resistivity measurement is based on core sampling of a small number of anodes in limited locations and may not be representative of the global anode resistance. The current study proposes a non destructive method that reproduces the current distribution in service and provides immediate results. Such results could be used to improve anode resistance and help potrooms cope with anode batch variability.

Introduction

Anode electrical resistance has an important impact on pot energy consumption due to its significant contribution to the cell voltage drop. The stub hole area is a critical part as the current density is high around the stub hole. Moreover, the upper part of the anode has a much more important contribution to the anode voltage drop than the lower part, as its life in the cell is longer.

Anode resistance can vary within an anode and between anode batches. Raw materials, anode forming, and anode baking have an impact on anode resistance. Anode resistance is also affected by current orientation. For example, current lines are horizontal in the stub hole area and essentially vertical in the other parts of the anode. All these sources of variability challenge the improvement of the anode quality. Moreover, this variability has an impact on the ACD achieved.

The current method used to evaluate anode resistivity is based on anode core sampling. The electrical resistivity of carbon is measured on small samples: 50 mm Ø and 100 mm long. Typically, about 0.5% of the anodes produced are cored and one sample per anode is analyzed. The small size of the sample and the small amount of core samples may not be representative of the entire anode. Moreover, there is always a delay - up to several weeks - between the sampling and analysis results.

It is known that the electrical resistivity of carbon is a function of temperature and that the resistivity measured at 950°C is about 80% of the resistivity measured at room temperature [1]. It is thus theoretically possible to predict the contribution of carbon resistivity in the pot rooms from measurements taken at room temperature. Only a few smelters measure the anode voltage drop during pot operation and the methods used do not allow distinguishing the following contributions: carbon material, anode rod and stub to carbon contact. A variation of 1µohm.m in carbon resistivity corresponds to 3 to 5 mV. The variability due to the carbon material can reach several tens of millivolts.

There are references describing a measurement method on an entire anode. However, the device described in the literature does not reproduce the current distribution in service [2,3].

In the following section, a device for the instantaneous measurement of electrical anode resistance (MIREA device), reproducing the current distribution in service, will be described. The contribution of the different parts of the anode (from the top to the bottom) to the anode resistance has been investigated with the MIREA device. The contribution of the anode hole area was also examined. Anodes from different forming processes were tested and results were compared to those obtained from intensive anode core sampling and subsequent electrical resistivity measurements.

Experimental Section

The MIREA device is portable, allowing the introduction of the current radially through the stub holes via inflatable metallic bags in order to mimic the way the current is introduced into the anode during electrolysis (Figure 1). The current is picked up at the bottom of the anode through metallic brushes. An aluminium stand was specially designed for the anodes. The current (200 A) is produced by a micro-ohmmeter (DLRO200 from Megger) and introduced in the metallic inflatable bags via conductors.

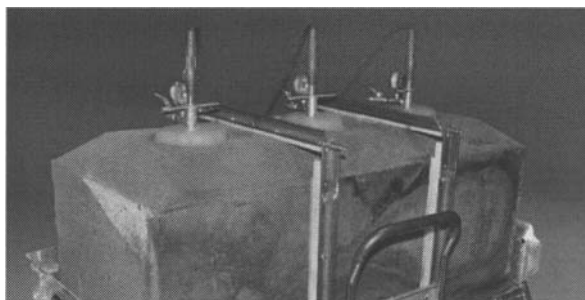


Figure 1. MIREA device.

Voltage measurements can be performed at different locations on the anode, as shown in Figure 2, using a template manufactured for this purpose. Measurements taken between two probes located below the stub hole - where the current lines are rather vertical - represent the contribution of the carbon material. Measurements taken between the reference probe and a probe located near to the top of the anode represent the electrical contribution of the stub hole area. A gauge R&R study was performed with the template to ensure the reproducibility and the repeatability of the measurements. It is possible to measure up to six anodes per hour (mainly a function of anode handling).

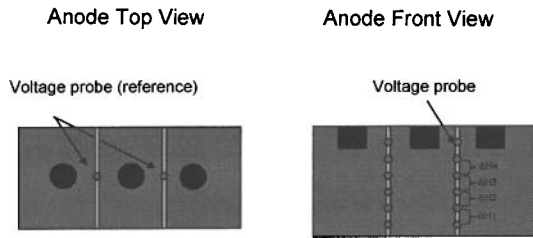


Figure 2. Location of Voltage Probes.

Anode core sampling was carried out according to the patterns shown in Figures 3 and 4. Electrical resistivity measurements of core samples were taken using an ABB apparatus.

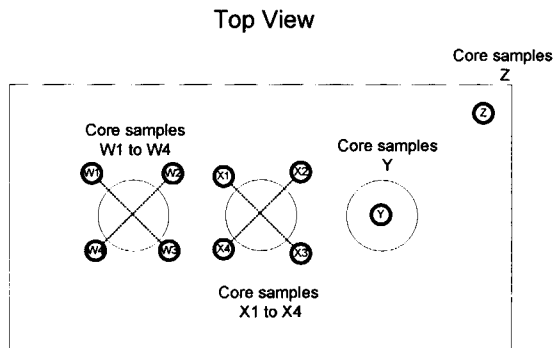


Figure 3. Top View of the Core Sample Locations.

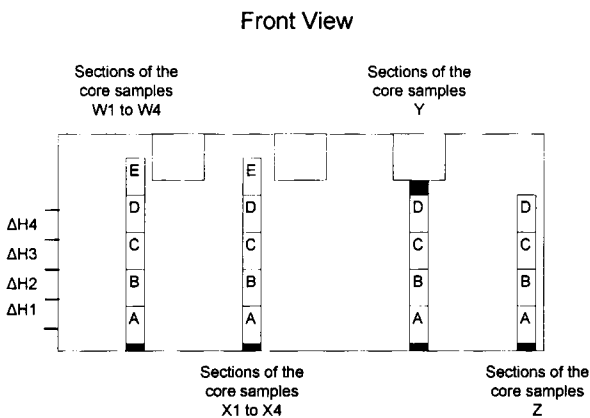


Figure 4. Front View of the Core Sample Section Locations.

Results

Anode Resistance Heterogeneity

Intensive core sampling was carried out on six vibrated anodes issued from a same batch of production and baked together. Forty-eight core samples were analyzed for each anode. The results of the intensive core sampling campaign reveal the heterogeneity within an anode in the vertical and horizontal planes.

Figure 5 presents the core sample electrical resistivity (all core sample locations included). One can observe that there is some heterogeneity between the core samples located in the anode stub hole area (W_i, X_i and Y) and at the end of the anode (Z).

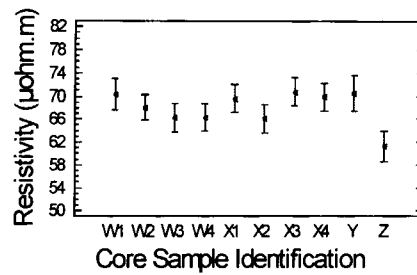


Figure 5. Electrical Resistivity of Vibrated Anodes as a Function of Core Sample Locations (Horizontal Plane).

There is also vertical heterogeneity within an anode as shown in Figure 6, for each section of core sample. Electrical resistivity reaches a maximum near the centre of the anode.

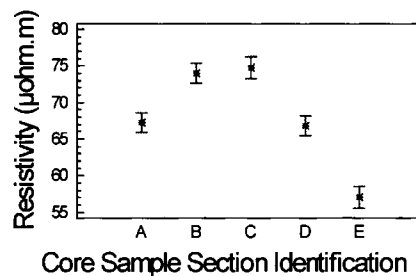


Figure 6. Electrical Resistivity of Vibrated Anodes as a Function of Core Sample Section Locations (Vertical Plane).

Instantaneous Measurement of the Anode Resistance with the MIREA Device

Anodes from the same batch of production as the one mentioned in the previous section were tested with the MIREA device (20 vibrated anodes were tested). Figure 7 represents the distribution of resistivity between two consecutive probes ($\Delta H_i=80$ mm) (Figure 2). This corresponds roughly to the location of anode core sample sections (Figure 4). The location of voltage probes is described in the experimental section. One can observe that the resistivity reaches a maximum near the centre of the anodes, as it was the case with core sample analysis.

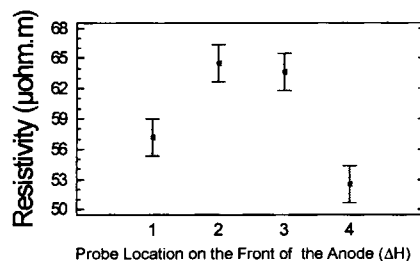


Figure 7. Electrical Resistivity of Vibrated Anodes Measured with the MIREA Device, as a Function of Probe Locations on the Vertical Anode Surface.

Pressed anodes were produced during the same day as vibrated anodes and baked at the same time. The overall electrical resistivity of pressed and vibrated anodes was investigated. The MIREA device confirmed that vibrated anodes are less resistive than pressed anodes (Figure 8).

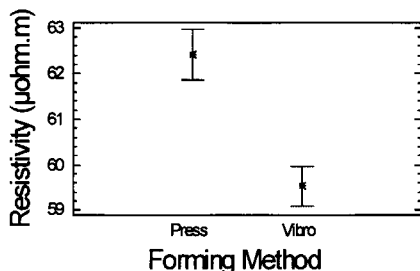


Figure 8. Impact of the Forming Process on the Electrical Resistivity of Anodes, Measured with the MIREA Device.

The anode resistance around the stub hole was also measured. The results presented in Figure 9 tend to show that vibrated anodes are less resistive than pressed anodes in the stub hole area.

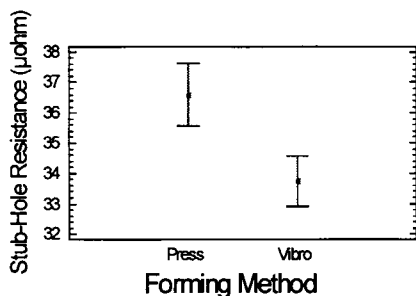


Figure 9. Impact of the Forming Process on the Electrical Contribution of the Stub Hole Area, Measured with the MIREA Device.

Core sampling was performed on the least resistive anode and on the most resistive anode of a measurement campaign carried out with the MIREA device, according to the pattern described in the experimental section. The electrical resistivity of the core samples was measured. The results were compared to those obtained with the MIREA device on these anodes. Again, voltage measurements were performed at different anode heights. The results presented in Figure 10 show a good correlation between the two methods.

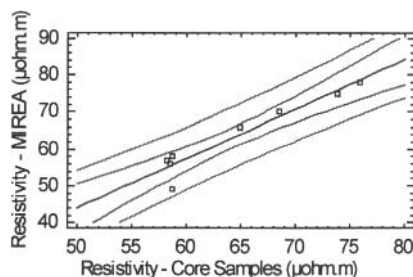


Figure 10. Correlation Between the MIREA Device Results and Core Sample Analysis Results.

(Correlation coefficient = 0.96 ; R-squared = 91.7 percent).

Practical Case

In another plant, an anode batch was manufactured and then baked in the same pit. Anodes issued from the same rows were analyzed with the MIREA device. The results are displayed in Figure 11. One can observe that some anodes present a high electrical resistivity and some anodes present a low electrical resistivity.

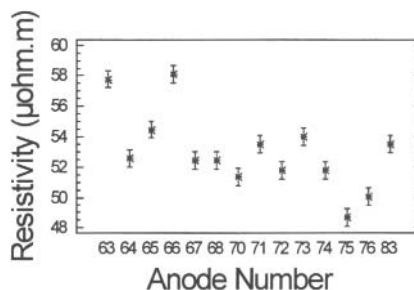


Figure 11. Electrical Resistivity of Anodes Measured with the MIREA Device.

One of each low/high resistivity anode was cut in order to assess the presence of cracks to explain the higher resistivity. Pictures of the half-anodes were taken (Figures 12 and 13). It can be seen from the photographs that more (and larger) cracks are apparent in the most resistive anode compared to the less resistive one.

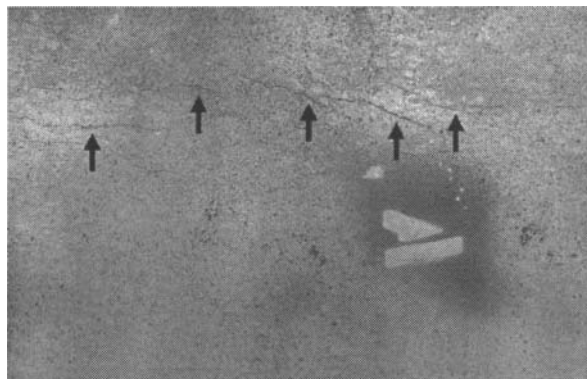


Figure 12. High Electrical Resistivity Anode (No. 66).

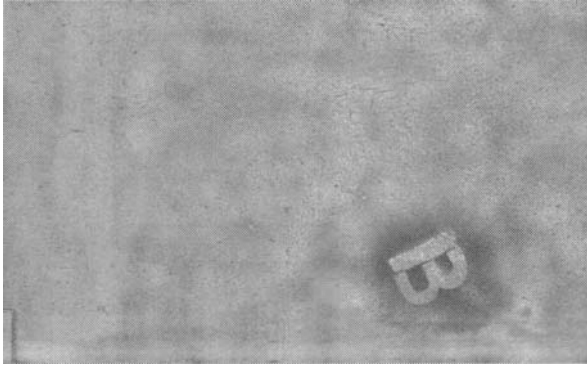


Figure 13. Low Electrical Resistivity Anode (No. 75).

Conclusions

The MIREA device offers an advantageous alternative for the measurement of anode resistivity. The anode resistance can be determined with a current distribution similar to that seen in operation. Moreover, it is possible to quantify the variation of resistivity within an anode. It is a proven device to qualify experimental anodes for R&D purposes.

An on-line MIREA device could be used as a process control tool for the anode shop and also the potlines. In the latter case, proactive actions on cell voltage could be taken. It would particularly be of interest in the context of amperage creep in a smelter or during a major refurbishing (or upgrade) of the anode plant.

References

1. S. Wilkening and J. Côté, "Problems of the Stub-Anode Connection", *Light Metals*, (2007), 865-873.
2. E. J. Seger, "Method and Means for Measuring Electrode Resistance", US patent 3,235,753, (1973).
3. E. J. Seger, "New Method of Measuring Electrode Resistance for Quality Control", *Light Metals*, (1975), pp. 283-290.

Acronyms

MIREA = Mesure Instantanée de la Résistance Électrique des Anodes.