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Attempt to use computed tomography CAT to analyze the anodized layer

Małgorzata Grabowska[1], Anna Piochacz[2], Jarosław Robert Mikołajczyk[3]

[1] Zakład Rezonansu Magnetycznego, Wojewódzki Szpital Zespolony w Toruniu; e-mail: gragosia@op.pl
[2] Zakład Obróbki Aluminium ZOBAL, Trzcianka k. Piły; e-mail: ania.piochacz@gmail.com
[3] Stanisław Staszic University of Applied Sciences in Piła; e-mail: jmikolajczyk@puss.pila.pl

Abstract: The process of anodizing aluminum surfaces is connected with many variables, e.g. the current density, process duration, process temperature, applied process operations (e.g. brushing), which can be influenced in order to optimize the process. The activities which consist in obtaining corrosion resistant surfaces have always been topical and desired. The article presents test results of anodized layer with the use of Somatom Definition AS, a computer-assisted tomograph of Siemens make, and they were compared with results obtained in non-destructive method. Aluminum alloy EN AW 6060 was used as the material of samples.

Key words: electroplating, anodizing, Computed Axial Tomography, tomograph

1. Introduction

The practice of galvanizer shows that the thickness of coating electrolytically deposited on a cathode depends on the time of depositing and value of current flowing through the bath. However, few electrolytic processes run strictly in accordance with Faraday's law because a part of electric current may be used for secondary processes, e.g. hydrogen release. Electrolytically deposited coating has no homogeneous thickness on the entire surface, especially on complex shape objects [5]. This complex phenomenon may be caused by, inter alia:

- geometric shape of a cathode;
- phenomenon of polarization;
- bath cover ability;
- distribution of the current density on a cathode;
- type of bath;
- uneven bath temperature;
- throwing power of a bath.

Most often the thickness of coating is greater on sharp edges and convex spots than in recesses (Fig. 1). Sometimes, in order to obtain a more uniform coating distribution, on the cathode surface applied are anodes adjusted by shape and size to the covered object (Fig. 2). However, in many cases, e.g. in case of a body of a car, such a procedure – because of practical reasons – is rendered very difficult or simply physically impossible considering a complex shape of a given product, frequent changes in the construction, series production volume, increased costs of manufacture, etc. The main factor which influences the thickness of the coating and its structure is the current density. Fig. 3 presents the current density distribution in [A/dm^2] on a flat cathode in a chromium plating bath. The current density is calculated from the thickness of the coating in different cathode places. Both cathode and anode were of equal geometric dimensions and they were placed in parallel to each other.

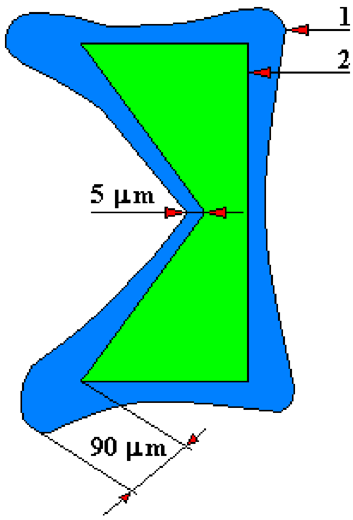

Fig. 1. Example of the nickel coating thickness distribution on a complex shape [5]: 1 – coating; 2 – cathode

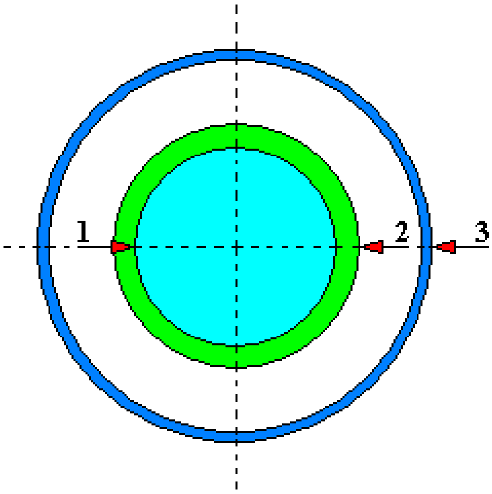

Fig. 2. The effect of anode shape matching on coating uniformity [5]:
1 – cathode; 2 – coating; 3 – anode

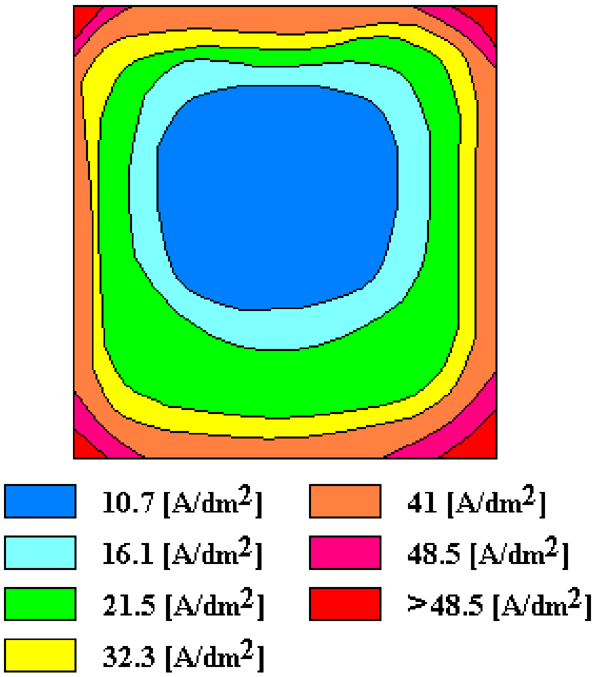

Fig. 3. Current density distribution on a flat cathode during chromium plating [3]

If the cross-section of the electrolyte pole is much bigger than the surface of electrodes, then their edges are burdened very strongly. This is so because the current reaches the electrode edges through a wide layer of electrolyte located outside the inter-electrode zone.

Anodizing is one of conversion coating and it consists in creating aluminum oxide on the aluminum surface. The coating created during this process is harder and more resistant to corrosion than the layer formed in a natural way. The oxide layer formed in a bath of sulfuric acid solution, chromic acid solution or oxalic acid may in principle increase only to a certain defined thickness. As the layer increases, its electrical resistance is growing, therefore with a constant voltage the current intensity is decreasing which caused a retardation of anodic reaction. After a certain period of time the speed of layer growth matches the speed of dissolution of Al_2O_3 and the layer thickness remains unchanged (Fig. 4).

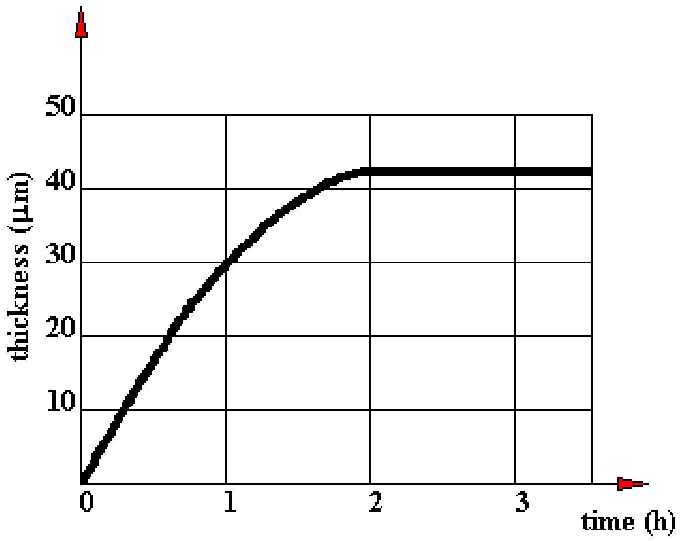

Fig. 4. Change in the thickness of anodic oxide coating in sulfuric acid at 20°C at current density 1.6 A/dm^2 [4]

Tomography is very young and modern discipline whose emergence and development is integrated with other sciences, e.g. mathematics, informatics, electronics, physics, medicine. With the use of tomography apparatuses it allows to produce tomographs, i.e. tomograms. From the produced tomographs it is possible to build a three-dimensional model of a tested object. A fundamental principle of tomography says that tomographs are obtained when two out of three basic elements of the system – a lamp/X-ray source, film/system of detectors, examined object – are moving during the exposure and direction of each of elements is opposite but their movement trajectories are homothetic. Tomographs used today may have several sources of radiation and several systems of detectors, and each of the systems may have dozens/a few hundred of detectors.

The aluminum alloy EN AW-6060 was selected as the material of samples for these tests; it is characterized by a big resistance to corrosion, average tensile strength and average fatigue strength. Tested samples measured 30 × 10 × 100 [mm]. The goal of tests was to determine the impact of anodizing duration on the thickness of obtained layers. TOP CHECK test apparatus was used for examining the thickness of anodized layers.

Samples with numbers: 1, 4, 5 and 6 were anodized in identical conditions as regards bath temperature and current density values. Only the duration of anodizing was a variable parameter for the listed samples. The duration of anodizing process for tested samples is presented in Table 1. The bath temperature for these samples was +18°C, and the current density 1.2 A/dm^2 [1, 2].

Table 1. Duration of the anodizing process [min] for individual samples [own study]

Sample No.	Duration of the anodizing process [min]
1	40
4	10
5	30
6	54

2. Test results

For measured thickness of anodized layers calculated were average values for individual samples which are presented in Table 2. Next, a diagram was drawn up showing the dependence of average thickness coating on the duration of anodizing process, which was presented in Fig. 5. Reconstruction of samples presented Fig. 6-13. In the Table 3 presented measured thickness of X-rays echo.

Note: The thickness of coating was measured on flat surfaces. Not on edges.

Table 2. Average thickness values of the anodized coating for tested samples [own study]

Sample No.	Average thickness values of the anodized coating for tested samples [μm]
4	2.998
5	10.000
1	16.010
6	26.010

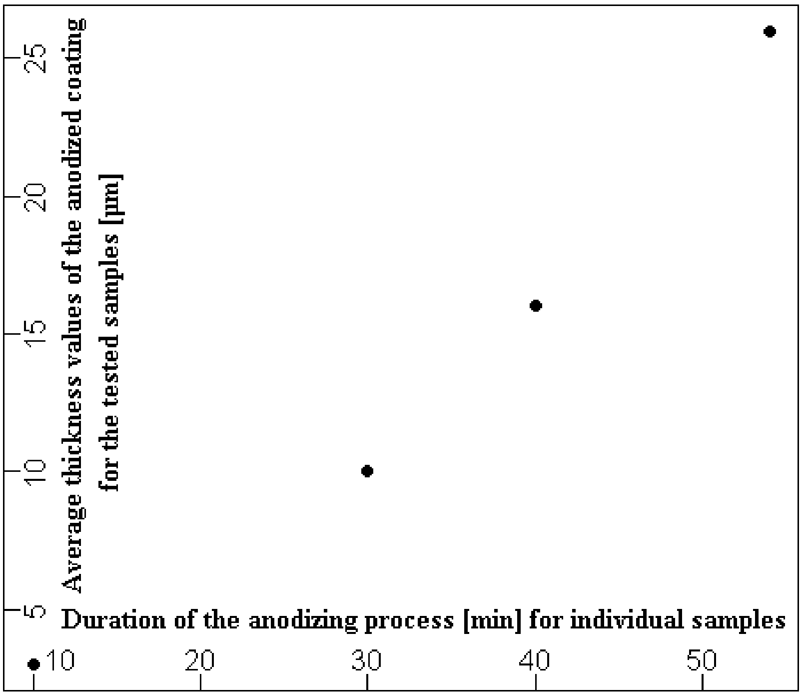

Fig. 5. Dependence of the average thickness of the anodized coating on the duration of the anodizing process for a fixed temperature +18°C and a fixed current density 1.2 A/dm^2 [own study]

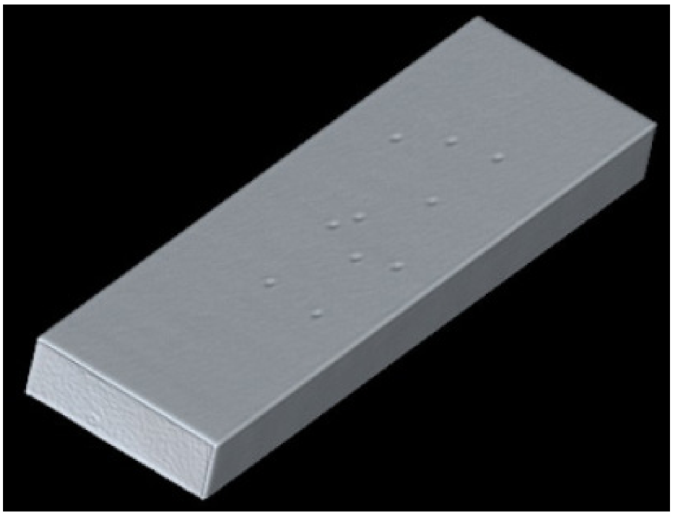

Fig. 6. Reconstruction of sample No. 4; visible traces after a hardness test using the Rockwell method [own study]

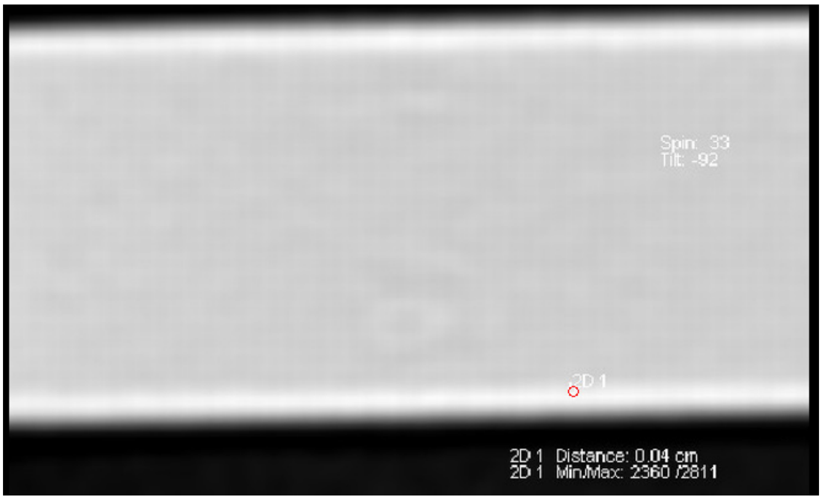

Fig. 7. Example of a cross-section; measurement of reflection (echo) from the edge surface of the sample – sample No. 4 [own study]

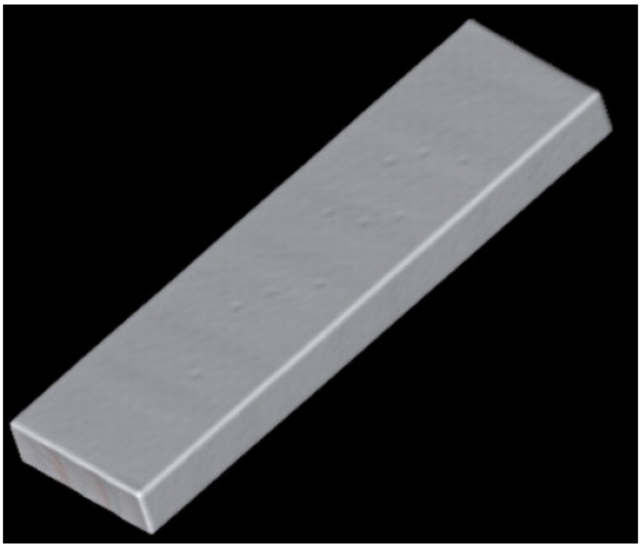

Fig. 8. **Reconstruction** of sample No. 5; visible traces after a hardness test using the Rockwell method [own study]

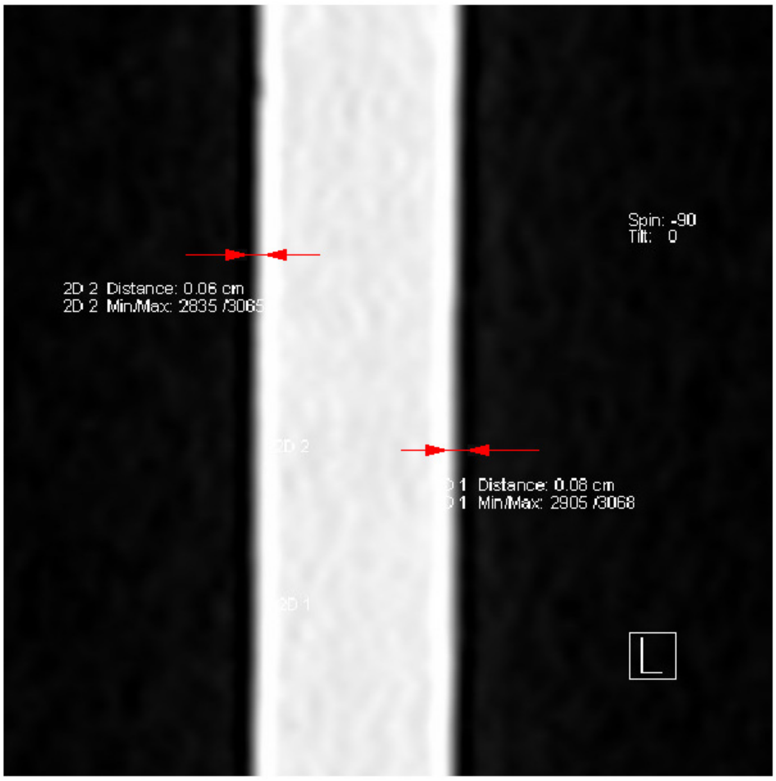

Fig. 9. Example of a cross-section; Measurement of reflection (echo) from the edge surface of the sample – sample No. 5 [own study]

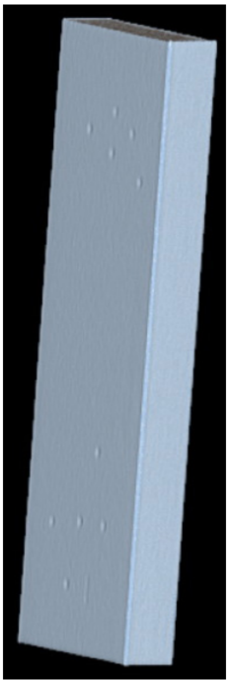

Fig. 10. Reconstruction of sample No. 1 (duration of the anodizing process 40 min); visible traces after a hardness test [own study]

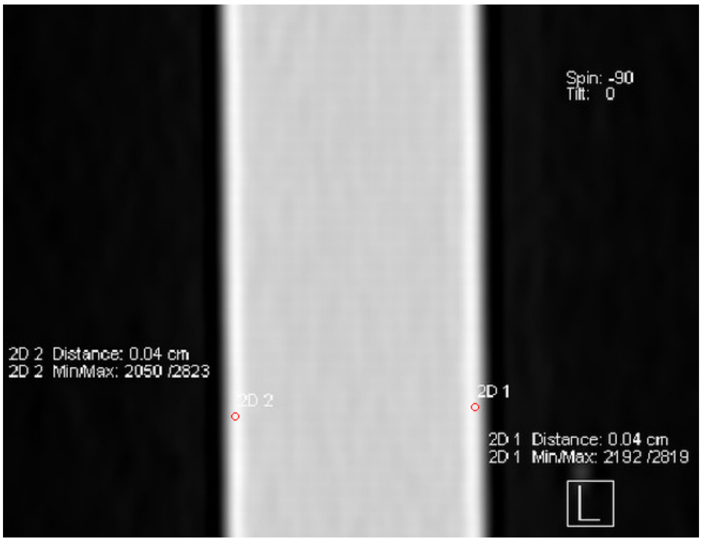

Fig. 11. X-ray echo (reflection) thickness measurement – sample No. 1 [own study]

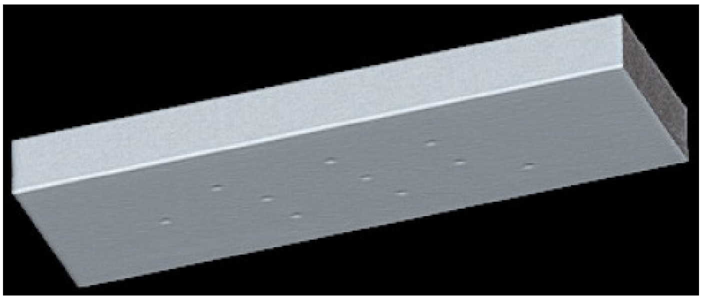

Fig. 12. Reconstruction of sample No. 6; visible traces after the hardness test [own study]

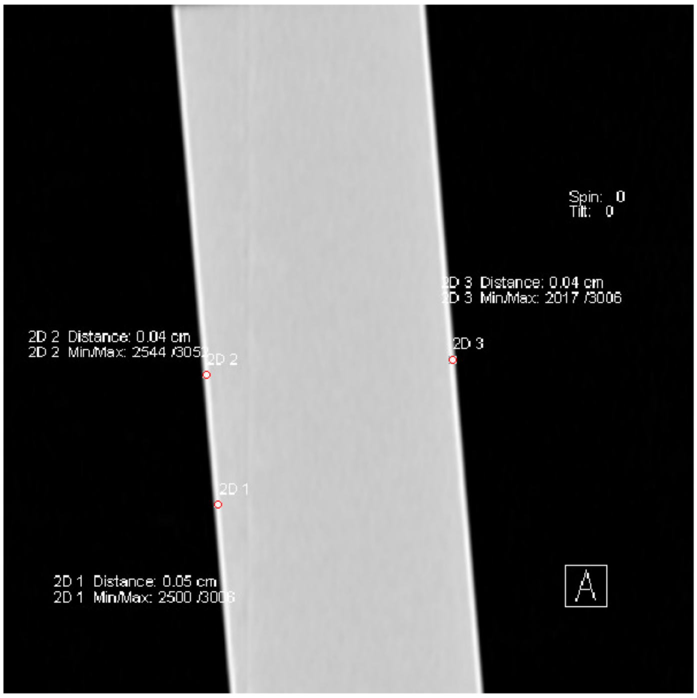

Fig. 13. X-ray echo (reflection) thickness measurement – sample No. 6 [own study]

Table 3. Measured thickness of X-rays echo [own study]

Sample No.	Measured thickness of X-rays echo
4	0.4 mm; 0.5 mm
5	0.6 mm; 0.8 mm; 0.8 mm; 0.7 mm; 0.6 mm
1	0.4 mm; 0.3 mm; 0.4 mm; 0.4 mm; 0.5 mm
6	0.4 mm; 0.4 mm; 0.5 mm; 0.5 mm; 0.4 mm

3. Summary

On the basis of tests carried out the following conclusions can be reached:

- The thickness of anodized layer has not impact on the size of X-rays echo (reflection) from the anodized layer. This might be prompted by the fact that the layer of Al_2O_3 is so small (thin) that it weakly absorbing the X-radiation compared with aluminum itself. The greatest thickness of the anodized layer was obtained in these tests for the anodizing duration of 54 minutes (sample No. 6) for which the thickness was 26.01 μm. Still, echo was observed for this layer thickness. The thickness of anodized layer obtained in the research paper [Wernik, Pinner] was about 42 μm (for anodizing duration of 120 minutes) – so much more. It is hard to determine whether for a high thickness of anodized coating the X-rays reflection (echo) will disappear or will be below the sensitivity threshold of the computer-assisted tomograph applied in these tests.
- With the application of the computer axial tomography CAT, using Somatom Definition AS computer-assisted tomograph of Siemens brand, it is rather impossible to determine the thickness of anodized layer or its features (texture, defects of the structure, etc.).

Literature

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