OPTIONS SURFACE TREATMENT ALUMINUM STRUCTURAL COMPONENTS

MIROSLAV GOMBAR[1], JAN KMEC[1], ALENA VAGASKA[2]
LYDIA SOBOTOVA[3], MIROSLAV BADIDA[3]
[1] Institute of Technology and Business
Department of Mechanical Engineering
Ceske Budejovice, Czech Republic
[2]Technical University of Kosice
Faculty of Manufacturing Technologies
Department of Mathematics, Informatics and Cybernetics
Presov, Slovak Republic
[3] Technical University in Kosice
Faculty of Mechanical Engineering
Department of Process and Environmental Engineering
Kosice, Slovak Republic

DOI : 10.17973/MMSJ.2016_11_201655

e-mail : gombar@mail.vstecb.cz

The contribution examines the effects of the electrolyte chemical composition on the resulting AAO layer thickness, which is one of the main indicators of corrosion protection of aluminium parts and which also favourably affects mechanical properties of component surfaces. For comparison purposes, there were selected the electrolytes comprising sulphuric acid and sulphuric acid with sodium chloride. Anodizing time for both samples was 210 minutes. The results obtained lead to the assumption that it is possible to replace conventional electrolytes by those that are more environmentally friendly, reduce the costs of their disposal and allow obtaining oxide layers of the same thickness. Detected difference of thickness of formed surface layers was moving in range $1\text{-}1{,}50\cdot10^{-3}$ mm, with lowering the amount of used chemical substances and amount of used electrical energy on half of original amounts, at the same time. Here you should describe the paper idea in short.

KEYWORDS
anodizing, surface treatment, thickness

1 INTRODUCTION

TheseAnodic aluminium oxide (AAO) coating has recently attracted the scientists' attention because of its self-organizing nature of vertical (cylindrical) pores in the form of hexagonal arrays, which provides a controlled and narrow distribution of pore diameters and inter-pore distances in addition to the possibility of forming the pores with extremely high aspect ratio [Rahimi 2009]. Anodizing is one of the most important processes in corrosion protection and colour finishes for aluminium [Vrublevsky 2005]. Anodizing of aluminium surfaces is carried out in a wide variety of plants for numerous uses in industries. It is an effective process applied to producing decorative and protective films on articles made from aluminium.

With the oxidation of aluminium, when forming the electrolyte, the most frequently used are sulphuric acid and oxalic acid, alternatively a combination of them, because of their environmental friendliness. The mechanism of an oxide layer formation when using sulphuric acid solution has been examined by [Tsagkaraki-Kaplanogloua 2006a], [Patermarakis 1998], [Aerts 2009], who managed to design a mathematical model of local turbulences in the electrolyte and examine their influence on the geometrical dimensions of the pores [Tsagkaraki-Kaplanogloua 2006b]. Aerts et al. were also dealing with the temperature effect on the growth of the oxide layer [Aerts 2010] and the layer porosity [Aerts 2007], of 99,50 % aluminium using the electrolyte comprising sulphuric acid based on which it followed that the structure of the layer, the layer porosity, its thickness and hardness are not so much under the influence of the temperature of the electrolyte compared to that of the electrode.

2 EXPERIMENT IMPLEMENTATION

Impurities in aluminium could influence the results. That is why it is important to study the change in the growth mechanism of porous alumina films on pure aluminium [8]. Therefore, alloy EN AW 1050 - H24 with dimensions 101x70x1 mm was used for the samples. Each applied sample was degreased in a 38 % solution of NaOH at 55 to 60 °C for 2 minutes and stained in a 40 % solution of NaOH at the temperature 45 °C-50 °C for 0,50 min. Consequently, the sample was desmutted in a 4 % solution of nitric acid at the temperature 18 to 24 °C for 1 minute. Between each operation, the sample was rinsed with distilled water. A circuit diagram for the process of anodizing in a Hull cell is shown in Fig. 1. The use of the Hull cell allows todivide a sample into several areas having different current densities. Fig. 2shows a simulated distribution of current densities on the sample surface during the process of oxidation.

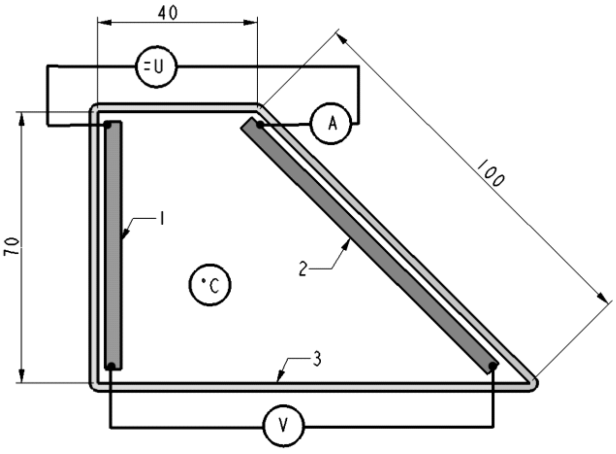

Figure 1. Circuit diagram 1-cathode, 2-anode, 3-Hull cell

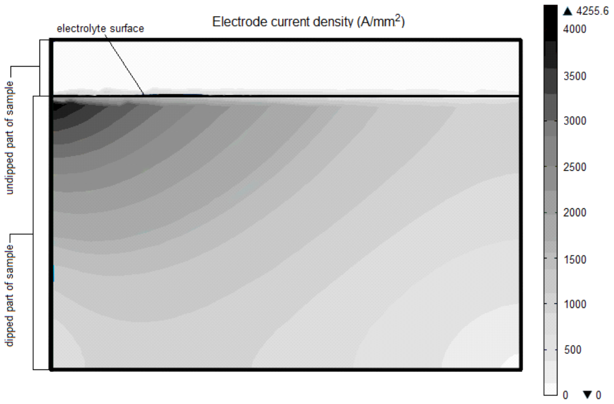

Figure 2. Current density distribution on the sample surface

Operating conditions of the oxidation process of individual samples (the composition of the electrolyte, temperature of the electrolyte, the magnitude of the applied voltage and duration of oxidation)is illustrated in Tab. 1.

Table 1. Operating conditions of the experiment

s.	H_2SO_4 [mol·l^{-1}]	NaCl [mol·l^{-1}]	T[°C] ±13,64%	U[V] ±4,17%	t [min]
1	2,16	0,00	22	12	210
2	1,08	$8{,}56\cdot10^{-3}$	22	12	210

3 RESULTS AND DISCUSSION

Statistical processing of the measured values was compiled graphical dependence (Fig. 3) which shows the ideal and measured thickness of the formed oxide layer and probability area of the formed oxide layer along the samples 1 and 2. Sample 1 was chosen as a comparative standard. Its electrolyte was made up of sulphuric acid with the concentration of 2,16 M, because such electrolyte with anodic aluminium oxidation is used the most often. The oxide layer, created on the top of the sample, is achieving layer thickness approximately $24\cdot10^{-3}$ mm in the areas with high current density and approximately $23{,}50\cdot10^{-3}$ mm in areas with low current density, which is presenting 2,08 % percentage decrease of the created oxide layer thickness, during the change of current density from maximum, to minimum values. Based on this, it is possible to consider thickness of formed oxide layer in electrolyte with sulphuric acid to be constant. On the surface of sample 2, which was oxidised in electrolyte composed of sulphuric acid with concentration 1,08 M and sodium chloride $8{,}56\cdot10^{-3}$ M, the oxide layer of thickness $23{,}00\cdot10^{-3}$ mm was formed, the areas with high current density and approximately $21{,}50\cdot10^{-3}$ mm in the areas with high current density, which is presenting 6,52 % percentage decrease of formed oxide layer within the change current density from maximum to minimum values. Evolution of thickness AAO layer along sample 2 has clearly decreasing tendency. On the other hand, from the angle of corrosion resistance the thickness of AAO layer $15{,}00\cdot10^{-3}$ mm is considered sufficient, that is why it is possible to consider AAO layer thickness $21{,}50\cdot10^{-3}$ mm (sample 2 area of low current density) as a above the average.

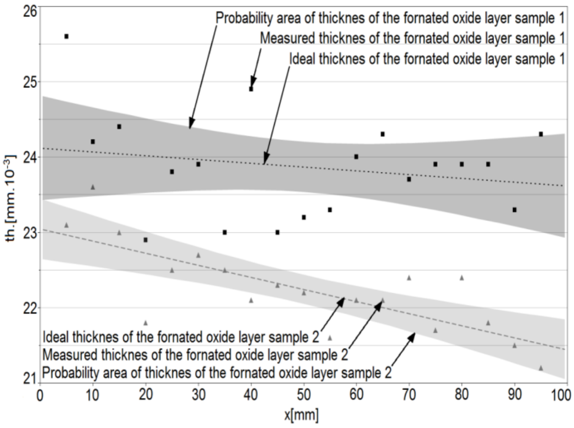

Figure 3. The resulting thickness of samples 1 and 2

Fig. 4 is comparing size of currents flowing through the circuit when the electrolyte for samples 1 and 2 is used during first three minutes of oxidation of samples. The Fig. 4 is showing, that during the use of the second electrolyte, through the circuit is flowing approximately 50 % lower current comparing to use of first electrolyte.

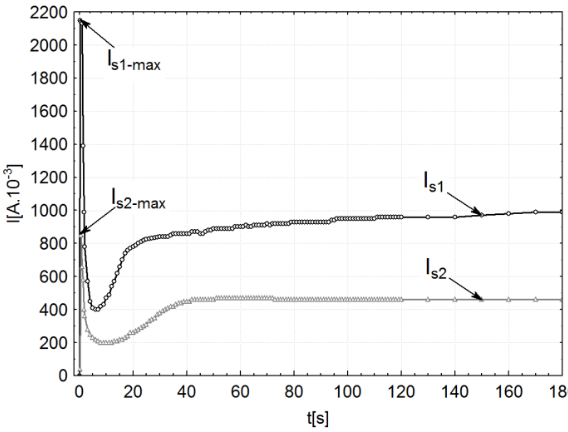

Figure 4. The dependence of the total electric current at the time of deposition

According Joule law (1) the lower current flowing through has direct influence on cooling the electrolyte. Based on this, the decrease of currents of 50 % means decrease of produced heat of 75 %. Lower heat production means lower amount of heat, which is needed to distract from the system by cooling. In conclusion this means lower consumption of energy while preserving the same temperature of electrolyte. In other words – while the same consumption of energy is needed, we can use lower temperature to form harder layer:

$$Q = R.I^2.t \qquad (1)$$

where:

Q –heat[J],

R – electrical resistance [Ω],

I – current [A],

t – time [s].

4 CONCLUSION

The research has brought new knowledge in the field of anodic aluminium oxidation. Detected difference of thickness of formed surface layers was moving in range 1 -$1{,}50\cdot10^{-3}$ mm, with lowering the amount of used chemical substances and amount of used electrical energy on half of original amounts, at the same time. Based on the results obtained, it is possible to optimize the technological process of anodic aluminium oxidation through:

1/ the costs reduction of chemicals required to create an electrolyte,

2/ reduction of electricity consumption,

3/ reduced demands for cooling, while maintaining the same quality of the formed layer.

Lower quantities of used chemical substances also have a positive impact on the environment and human health.

ACKNOWLEDGEMENT

The work was supported by Ministry of Education of Slovak republic VEGA 1/0537/15.

REFERENCES

[Aerts 2007] Aerts, T., Dimogerontakis, T., De Graeve, I., Fransaer, J. and Terryn, H. Influence of the anodizing temperature on the porosity and the mechanical properties of the porous anodic oxide film, Surface & Coatings Technology, 2007,No.201., pp 7310–7317, ISSN 0257- 8972

[Aerts 2009] Aerts, T., Degraeve, I., Nelissen, G., Deconinck, J., Kubacki, S., Dick, E. and Terryn, H. Experimental study and modelling of anodizing of aluminium in a wall-jet electrode set-up in laminar and turbulent regime, Corrosion Science,2009, Vol.51.,pp 1482–1489,ISSN 0010-938X

[Aerts 2010] Aerts, T., Degraeve, I. and Nelissen, G. Comparison between the influence of applied electrode and electrolyte temperatures on porous anodizing of aluminium, Electrochimica Acta, 2010, No.55., pp.3957–3965, ISSN 0013-4686

[Patermarakis 1998] Patermarakis, G. Development of a theory for the determinativ of the composition of the anodizing solution inside the pores during the growth of porous anodic Al2O3 films on aluminium by a transport phenomen on analysis, Journal of Electroanalytical Chemistry, 1998, No.447.,pp25–41, ISSN 1572-6657

[Rahimi 2009] Rahimi, M. H., Sarama,D. S., Tabaian, S. H., Marashi, S. P., ZolfagharI, A. and Mohammad Alinezhad, M. Study the effect of striping in two-step anodizing process on pore arrangement of nano-porous alumina, Applied Surface Science, 2009,No.256., pp.12–16, ISSN 0169-4332

[Tsangaraki-Kaplanogloua 2006a] Tsangaraki-Kaplanogloua, I., Theohari, S., Dimogerontakis, Th., Kallithrakas-Kontos, N., Yar-Ming, W., Hong-Hsiang, K. and Sheila, K. Effect of alloy types on the anodizing process of aluminum, Surface & Coatings Technology, 2006, No.200., pp2634 – 2641, ISSN 0257- 8972

[Tsangaraki-Kaplanogloua 2006b] Tsangaraki-Kaplanogloua, I., Theohari, S., Dimogerontakis, Th., Kallithrakas-Kontos, N., Yar-Ming, W., Hong-Hsiang, K. and Sheila, K. Effect of alloy types on the electrolytic coloring process of aluminum, Surface& Coatings Technology, 2006, No.200., pp 3969 – 3979, ISSN 0257-8972

[Vrublevsky 2005] Vrublevsky I., Parkoun V., Sokol V. and Schreckenbach, J. Analysis of chemical dissolution of the barrier layer of porous oxide on aluminium thin films using a re-anodizing technique, Applied Surface Science, 2005,No.252., pp 227–233, ISSN 0169-4332

CONTACTS:

Ing. Miroslav Gombar, PhD.
doc. Ing. Jan Kmec, CSc.
Institute of Technology and Business in Ceske Budejovice
The Department of Mechanical Engineering
Okruzni 10, 370 01 Ceské Budejovice, Czech Republic
tel.: + 420 387 842 195
e-mail: gombar@mail.vstecb.cz
Tel.: +420 387 842 195
e-mail: kmec@mail.vstecb.cz
www.vstecb.cz

Ing, Alena Vagaska, PhD.
Technical University of Kosice
Faculty of Manufacturing Technologies with a seat in Presov
Department of Mathematics, Informatics and Cybernetics
Bayerova 1, 080 01 Presov, Slovak Republic
tel.: +421 55 602 6430
e-mail: alena.vagaska@tuke.sk,
www.tuke.sk

doc. Ing. Lydia Sobotova, PhD.
Dr.h.c.mult.prof. Ing. Miroslav Badida, PhD.
Technical University in Kosice
Faculty of Mechanical Engineering
Department of Process and Environmental Engineering
Letna 9, 042 00 Kosice, Slovak Republic
tel.: + 421 55 602 2793
e-mail: lydia.sobotova@tuke.sk
tel.: + 421 55 602 2716
e-mail:miroslav.badida@tuke.sk
www.tuke.sk