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## APPLICATION OF ANODIZATION PROCESS FOR CAST ALUMINIUM SURFACE PROPERTIES ENHANCEMENT

An huge interest is observed in last years in metal matrix composite, mostly light metal based, which have found their applications in many industry branches, among others in the aircraft industry, automotive-, and armaments ones, as well as in electrical engineering and electronics, where one of the most important issue is related to the corrosion resistance, especially on the surface layer of the used aluminium alloys. This elaboration presents the influence of ceramic phase on the corrosion resistance, quality of the surface layer its thickness and structure of an anodic layer formed on aluminium alloys. As test materials it was applied the aluminium alloys Al-Si-Cu and Al-Cu-Mg, for which heat treatment processes and corrosion tests were carried out. It was presented herein grindability test results and metallographic examination, as well. Hardness of the treated alloys with those ones subjected to corrosion process were compared.

*Keywords:* Surface Treatment, Aluminium alloys, Ceramic materials, Composites, Corrosion resistance

## 1. Introduction

Aluminium and its alloys are characteristic of high corrosion resistance in the standard atmospheric conditions and in the environment of many acids, thanks to the  $\text{Al}_2\text{O}_3$  aluminium oxide layer developing on their surface [1-4]. Therefore, the corrosion resistance of aluminium depends on the solubility of its protective layer. Its tightness and good adhesion to the substrate, determining the corrosion resistance, is dependent on purity of aluminium or its alloys. Anodisation of aluminium is practically electroplating in reverse. During anodising the part is made the anode (positive electrode) in an electrolytic cell (Fig. 1) [5-8].

In the industry, both civilian and military there are used light metal alloys, differing in mechanical properties and corrosion resistance. Each of technical aluminum alloys require modifying of the surface treatment methods and the optimization of chemical processes based on the morphology analysis of the surface there can be found, that it is possible to obtain layers with more or less developed porosity. It depends mainly on the electrolytic process parameters:

- current density (process speed),
- temperature of the electrolyte (granularity),
- process duration.

However, in the industrial and marine environment that contain the aggressive salts this resistance deteriorates [6-8], similarly – the environments strongly affecting the aluminium and its alloys are the  $\text{SO}_2$  containing atmospheres coming from burning of oil or gasoline, and also atmospheres with a high content of chlorides. The corrosion

damage is promoted by contaminations found in the alloys, and also the inhomogeneity of the chemical composition. The environment of chlorides increases susceptibility of aluminium and its alloys to pitting corrosion, and presence of various contaminations prevents development of the compact protective layer; therefore, in these locations pitting centres may develop. The number of pits will be increasing the more alloy elements will be present being more cathodic than pure aluminium, causing acceleration of propagation of pits and promoting depassivation [7-11].

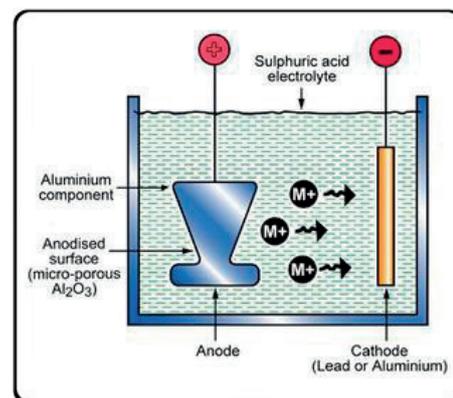


Fig. 1. Anodising process of aluminium in sulphuric acid electrolyte [Ecochillers.Inc]

The main goal of this work is to investigate the influence of the base material in form of aluminium with silicon and/or copper addition in pure form or mixed with  $\text{Al}_2\text{O}_3$  alumina powder on the structure and properties of the obtained anodised  $\text{Al}_2\text{O}_3$  layer.

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## 2. Material and investigations

For investigation the cast aluminium alloy AlSiCu3 as well as AlSi9Cu3 were used, with chemical composition presented in TABLE 1.

TABLE 1  
Chemical composition of the investigated alloys

| Chemical composition in wt. % |       |     |     |     |       |       |      |
|-------------------------------|-------|-----|-----|-----|-------|-------|------|
| alloy                         | Si    | Mg  | Cu  | Mn  | Fe    | Zn    | Al   |
| AlSi9Cu3                      | 9,5   | 1,5 | 3,0 | 0,5 | 0,9   | 0,5   | Rest |
| AlSiCu3                       | ≤0,20 | 1,2 | 3,8 | 0,3 | ≤0,30 | ≤0,25 | Rest |

TABLE 2  
Anodising parameters

| Anodising parameters | Value                                                                |
|----------------------|----------------------------------------------------------------------|
| electrolyte          | H <sub>2</sub> SO <sub>4</sub> with a concentration of 295 ÷ 315 g/l |
| anodisation current  | 3.5 A/dm <sup>2</sup>                                                |
| kathode              | platinum/lead                                                        |
| anode                | anodised material                                                    |
| temperature          | - 4/20 °C                                                            |
| time                 | 20 h                                                                 |

The aluminium alloy samples were subjected to the anodizing process in a sulphuric acid electrolyte containing H<sub>2</sub>SO<sub>4</sub>. The conditions and parameters of the electrolytic process in are presented in Table 2, the anodisation process was carried out in a glass vessel where the anode was connected to the sample and cathode was applied in form of titanium and lead sheet, a rectifier of the PDL t220type was used supplied by TESLA.

For determining the structure and properties of the obtained surface following tests and investigations were made:

Metallographic investigations were carried out on the light microscope OLYMPUS of the BX60M type equipped with a camera Olympus DP10. Recording and processing of images was made on a PC using the program analysis supplied by OLYMPUS.

Hardness tests of the fabricated composite materials were made on HAUSER hardness tester with the Vickers method at 10 N load, according to the Polish Standard PN-EN ISO 6507-1. Seven indentations were made on the transverse section diameter for specimens taken from bars obtained by extrusion, both for the AlSi9Cu3 aluminum alloy and for the fabricated composite materials reinforced with the Al<sub>2</sub>O<sub>3</sub> phases particles, to determine their average hardness.

Abrasion resistance wear tests were carried out using the

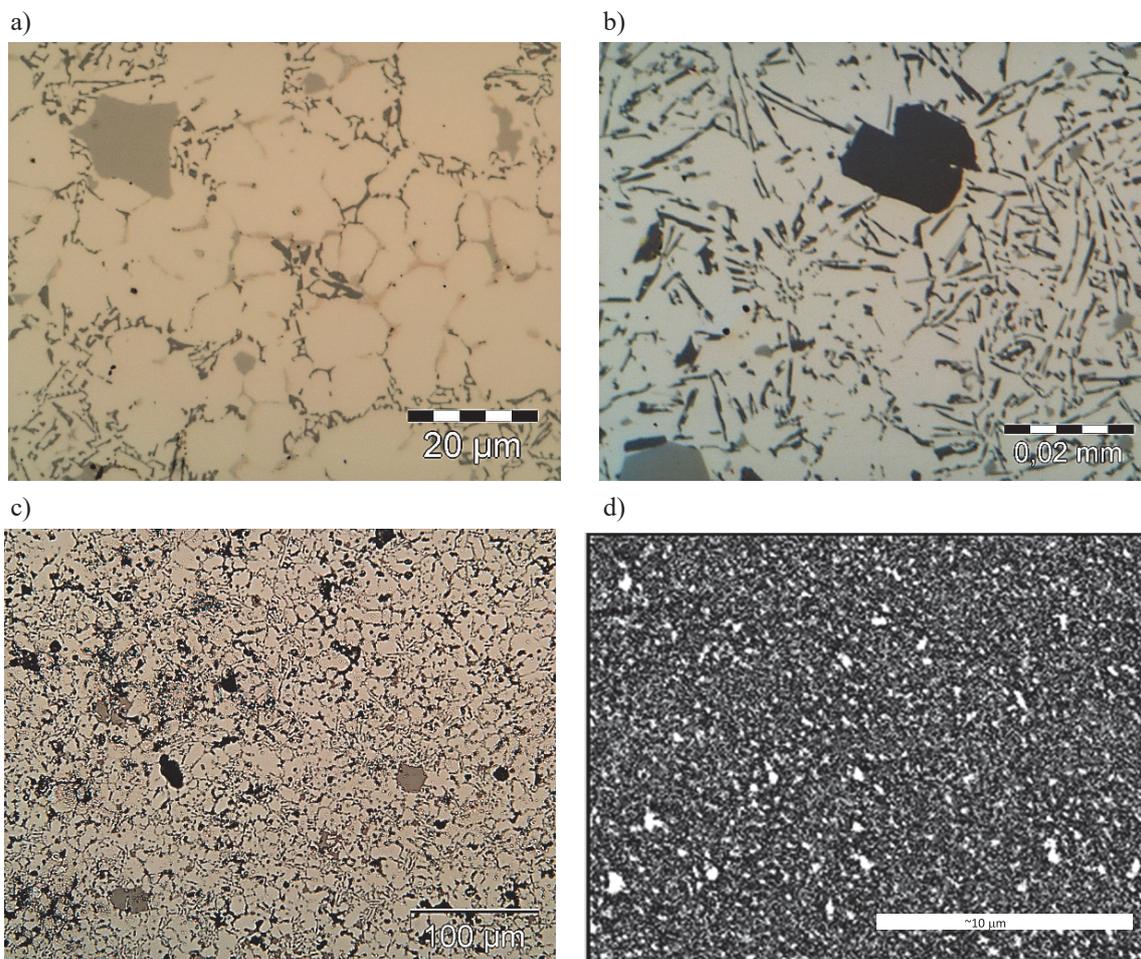


Fig. 2. Microstructure of the investigated alloys: a) AlSiCu3 alloy light microscope, b) AlSi9Cu3 alloy, light microscope, c) microstructure of the AlSi9Cu3 powder material, light microscope, d) AlSi9Cu3 alloy powder with Al<sub>2</sub>O<sub>3</sub> reinforcement, SEM

device designed at the Faculty of Mechanical Engineering of the Silesian University of Technology. Test pieces were 30 mm long. Preparation of the test pieces for tests consisted in grinding with the 1200 grit abrasive papers, to obtain four flat and even surfaces. Tests were carried out on surfaces prepared in this way using the steel balls with 8.7 mm diameter as the counter-specimens. Tests were carried out with the constant number of cycles of 5000 (120 m) at various loads: 4, 5, 6, 7, and 8 N. Test pieces were rinsed in the ultrasonic washer to clean them and next were weighed on the analytical balance with the accuracy of 0.0001 g to check the mass loss.

### 3. Investigation results

There is recognized a valuable difference in the microstructure of the AlSiCu3 and AlSi9Cu3 alloy, mainly concerning the increased silico additions, visible on Figs. 2a and 2b. The metallographic examinations of the investigated composite materials make it possible to observe the homogeneous distribution of the reinforcing material in the matrix; however, banding of the reinforcing particles parallel to the extrusion direction was noted on the longitudinal micro sections (Fig. 2).

After the anodization process the samples were cut lengthwise and mounted to examine the thickness and structure

of the samples by light and scanning microscope. The material is also subjected to X-ray analysis of the qualitative phase.

It was confirmed, using the X-ray qualitative phase analysis, that according to the assumptions made, composite materials were obtained and occurrences of reflections from ceramic particles phases and of the aluminum matrix material, were found on X-ray diffraction diagram (Fig. 3).

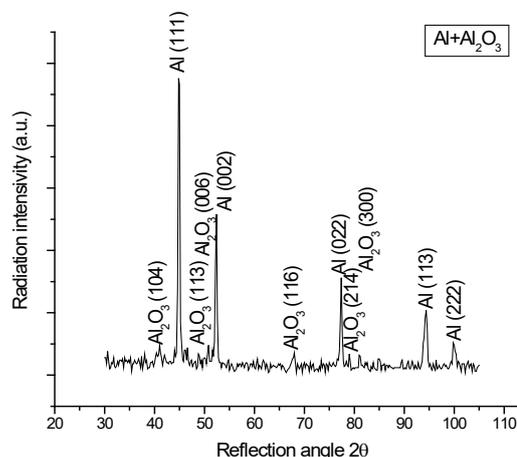


Fig. 3 X-ray diffraction patterns for aluminum matrix composite materials.

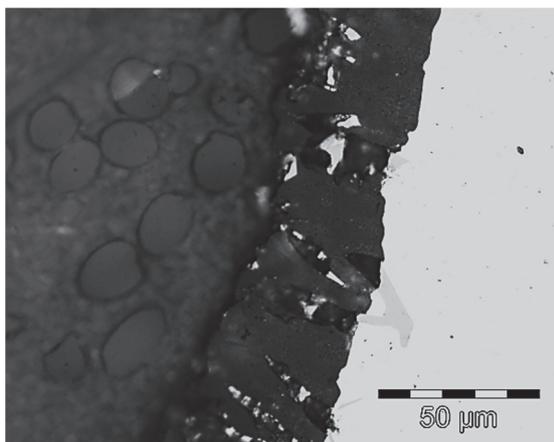


Fig. 4. Structure of the AlSi9Cu3 anodised bulk material surface layer.

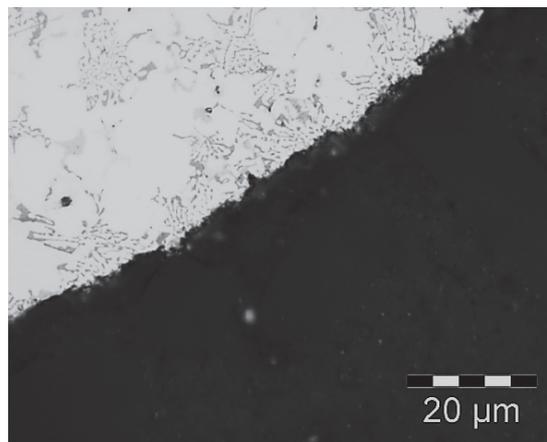


Fig. 5. Structure of the AlSiCu3 anodised bulk material surface layer.

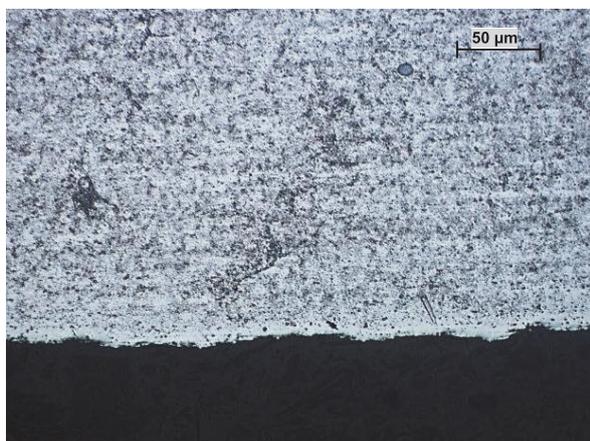


Fig. 6. Structure of the AlSiCu3 PM material, anodised surface layer without Al<sub>2</sub>O<sub>3</sub> powder addition

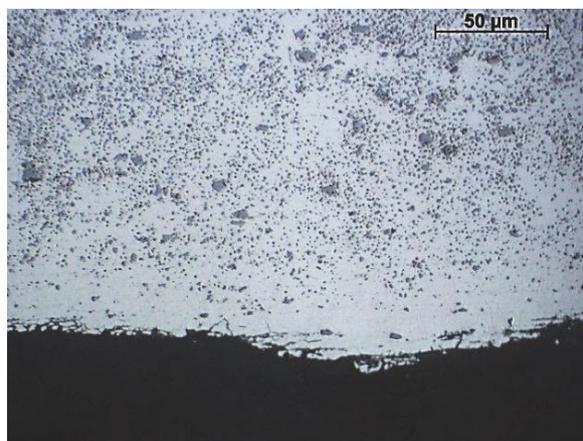


Fig. 7. Structure of the AlSiCu3 PM material anodised surface layer with 5% Al<sub>2</sub>O<sub>3</sub> powder addition



Fig. 8. Structure of the AlSiCu3 PM material anodised surface layer with 10% Al<sub>2</sub>O<sub>3</sub> powder addition

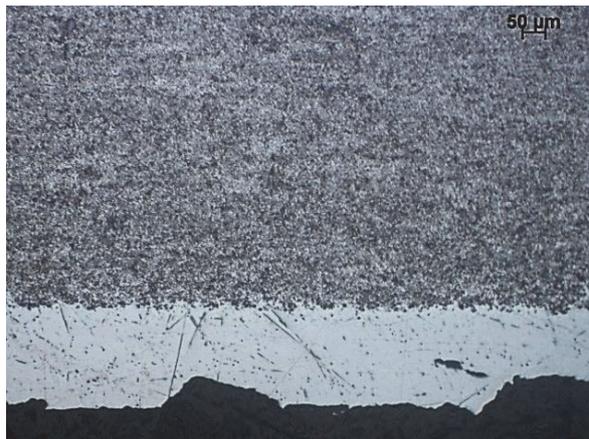


Fig. 9. Structure of the AlSiCu3 PM material anodised surface layer with 15% Al<sub>2</sub>O<sub>3</sub> powder addition.

Based on the structural investigations performed on the light microscope there can be observed the anode layer of different thickness and structure for bulk materials as well as the PM materials (Figs. 4-9).

Based on the obtained structure investigation of the anodised layer it was possible to determine the thickness of the alumina layer, the measurement results are presented in TABLE 3.

Hardness tests of the fabricated composite materials revealed its diversification depending on the weight ratios of the reinforcing particles in the aluminum matrix.

Mean hardness values of the aluminum alloy and of the fabricated composite materials reinforced with the Al<sub>2</sub>O<sub>3</sub> ceramic particles with the weight ratios of 5, 10 and 15% are shown in Fig. 10. Investigated composite materials are characterized by an higher hardness compared to the non-reinforced material. Hardness of composite materials increases with increasing content of the reinforcing material in the metal matrix.

Wear of the investigated materials versus load change at the constant distance is of a linear character (Fig. 11). Many factors affect the mass loss after the wear tests of the composite materials: hardness of the obtained composite materials, shape and dimensions of the reinforcement particles, and also values of load between the test piece and the counter-specimen.

Reinforcement of the soft aluminum matrix by hard Al<sub>2</sub>O<sub>3</sub> particles influence of the hardness growth (Fig. 10) but decrease the wear resistance of composite materials.

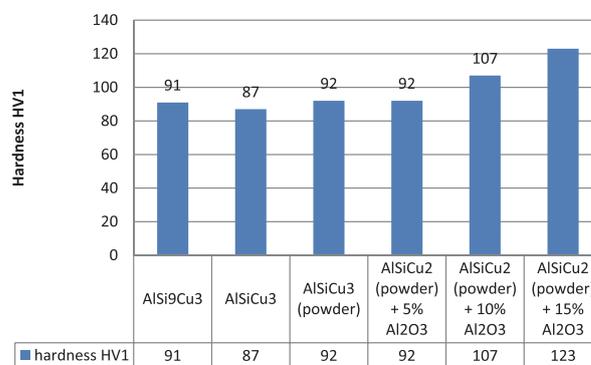


Fig. 10. Hardness of aluminum alloy and aluminum alloy composite materials reinforced with particles

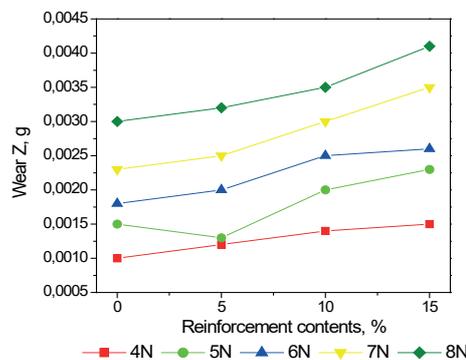


Fig. 11. Wear of the aluminium alloy and composite materials in the following states in the precipitation hardened state, at various load values, N

Thickness measurement results of the obtained anodic layer.

TABLE 3

| Parameter          | Value   |         |                  |                                                    |                                                     |                                                     |
|--------------------|---------|---------|------------------|----------------------------------------------------|-----------------------------------------------------|-----------------------------------------------------|
| Material           | AlSi9Cu | AlSiCu3 | AlSiCu3 (powder) | AlSiCu3 (powder)+5% Al <sub>2</sub> O <sub>3</sub> | AlSiCu3 (powder)+10% Al <sub>2</sub> O <sub>3</sub> | AlSiCu3 (powder)+15% Al <sub>2</sub> O <sub>3</sub> |
| Mean thickness     | 16.6    | 5.2     | 5.65             | 20.65                                              | 111.33                                              | 179.5                                               |
| Max thickness      | 19.8    | 8.6     | 7.25             | 22.18                                              | 115.4                                               | 183.67                                              |
| Min thickness      | 14.2    | 7.8     | 5.15             | 19.24                                              | 98.9                                                | 175.5                                               |
| Standard deviation | 1.17    | 0.58    | 0.55             | 1.47                                               | 9.24                                                | 4.08                                                |

#### 4. Conclusions

The test results shown that the rate of anodized both AlSi9Cu3 and AlSiCu3 show less weight loss when compared to alloys with Al<sub>2</sub>O<sub>3</sub> powder addition. It can be seen that the amount of the add powder affects the abrasion resistance; higher amounts exhibit less weight loss during the test performed, thus they have a greater resistance to abrasion.

The wear growth is increased according the increase of the alumina powder addition and is higher compared to the bulk material both AlSi9Cu3 and AlSiCu3 for smaller amount of the alumina powder addition the wear resistance is lower, because the particles easier fall out during friction with counter-specimens.

Based on the hardness measurement results, it can be concluded, that the samples with higher Al<sub>2</sub>O<sub>3</sub> powder addition have higher hardness compared to non-anodized materials. After anodizing its hardness has increased to 123 HV1.

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