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Anodization of cast aluminium alloys produced by different casting methods

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Abstract

In this paper the usability of two casting methods, of sand and high pressure cast for the anodization of AlSi12 and AlSi9Cu3 aluminium cast alloys was investigated. With defined anodization parameters like electrolyte composition and temperature, current type and value a anodic alumina surface layer was produced. The quality, size and properties of the anodic layer was investigated after the anodization of the chosen aluminium cast alloys. The Alumina layer was observed used light microscope, also the mechanical properties were measured as well the abrasive wear test was made with using ABR-8251 equipment. The researches included analyze of the influence of chemical composition, geometry and roughness of anodic layer obtained on aluminum casts. Conducted investigations shows the areas of later researches, especially in the direction of the possible, next optimization anodization process of aluminum casting alloys, for example in the range of raising resistance on corrosion to achieve a suitable anodic surface layer on elements for increasing applications in the aggressive environment for example as materials on working building constructions, elements in electronics and construction parts in air and automotive industry.

Keywords: Aluminium cast alloys, Mechanical properties, Surface treatment, Alumina layer, Anodization

1. Introduction

In environment conditions the surface of aluminium parts is naturally covered by a thin alumina Al_2O_3 layer. This layer has a thickness of a few tens of nanometers, depending on the material, environment and exposure time. With a properly chose anodization technique the thickness of the layer can be increased even to a value of some micrometers. Using this method the surface is more resistant against environmental factors like salt water, acidic solutions or external mechanical influence. Anodization is commonly used for corrosion protection of aluminium alloy parts and therefore exists international standards like ISO 7599 and DIN 17611 for determine the properties and quality of the anodic surfaces layers [1-5].

A progress in Materials Engineering made it possible to solve the problems connected with metallic materials strength satisfactorily as regards both structural and tool materials. It the continuous growth of use of alloys aluminum in different branches the wide comprehended industry as well as development of technology of production of aluminum and its alloys and composites with aluminum matrix was observed in last years in many scientific institutions [6÷9].

The anodic layers have a protective and decorative function applying on the aluminum electronic elements, articles of home farm, part of instruments, the gardens pieces of furniture, the tourist equipment and sport, the motor accessories and elements of aluminum woodwork. The oxides layers are produced on aluminum foil designed on electrode in condenser too. Hard anodic layers can be applied in air and motor industry [10-12].

The presence of intermetallic compounds of copper, which act as cathodic sites, makes copper containing aluminium alloys more vulnerable to corrosion attack. The high copper content makes aluminium alloy ones of the most difficult alloys to anodize. Production of thick anodic oxide films is possible only under conditions of hard anodizing while this alloy is easily subject to local burning. Film cracking caused by oxygen generation is also observed during the process of anodization of Al-Cu Alloys when thick porous oxides are produced. A specific characteristic of this alloy is that the oxidation of copper takes place during anodization after the formation of a relatively narrow region of copper enrichment at the alloy/film interface. This results in reduced current efficiency during film formation. This reduction has been also attributed to oxygen evolution above copper rich regions, an established inhibitor of corrosion of copper has been used to improve the current efficiency [13-16].

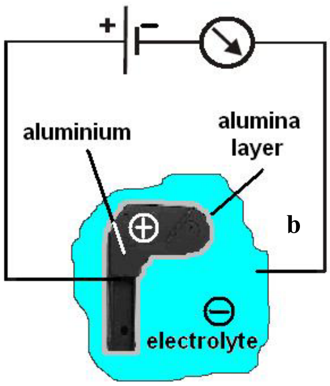

Fig. 1. Scheme of the anodization process including the anodized part, electrolyte, power supply and the alumina surface layer.

In the last decades intensive studies led to new insights to the principles underlying the anodization processes and help refining the methods to prepare porous surfaces. The anodization process itself consist of following steps:

- cleaning of the anodized parts (mainly different kinds of acid cleaners are used for removing of grease and dirt that was on the surface because of the production, handling and transport.
- pre-Treatment (consists of etching/brightening), small surface damages are removed within various etching processes. Brightening creates a brighter, more reflective appearance.
- anodizing
- coloring (electrolytic coloring, integral coloring, interference coloring)
- sealing (last step for pores closing)

As shown on figure 2, the anodic layer growth process involves four steps:

- barrier layer development
- growth of small inhomogenities
- continuously grow of pores
- stabilization of the interpore distances

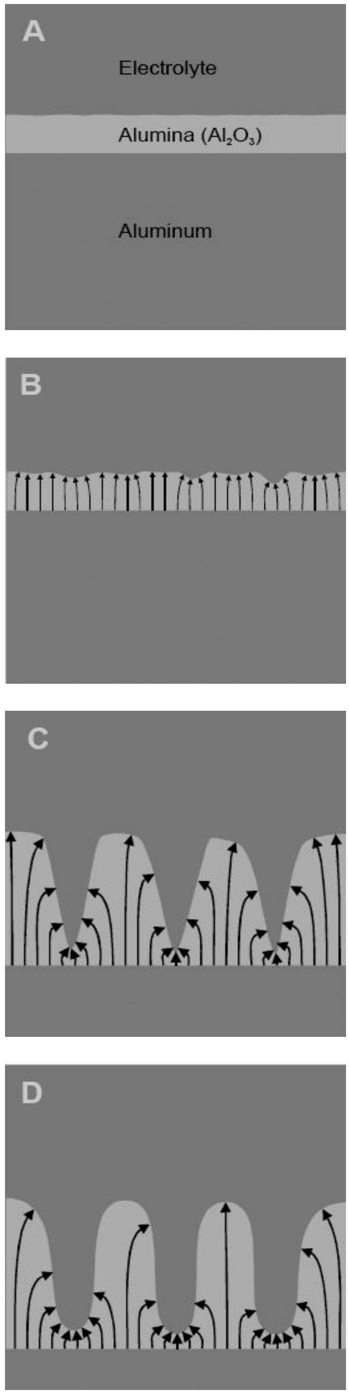

Fig. 2. Stages in the development of the alumina surface layer, a) barrier layer development, b) growth of small inhomogenities, c) continuously grow of pores, d) stabilization of the interpore distances (JPK Instruments AG, 2003).

The Al_2O_3 alumina layer growth process depends on the chemical composition of the anodized material, structure as well surface treatment. But the most important factor are the chosen anodic treatment conditions. The most important factors of the anodization treatment conditions are the electrolyte type, composition and concentration, the current type and current density used, as well as the process temperature. The continuously growing process of the pores during the ongoing anodization goes on with a speed of 1 – 2 μm/ h. The interpore distances can be adjusted in the range of 50 – 500 nm

The purpose of this research is the investigation of the structure and thickness of the alumina layers formed during anodic treatment of the aluminium sand and pressure cast alloys and comparison of the casting method onto the formed anodic layer.

2. Material and methods

2.1 Material for investigation

The analysis of geometry of surface was based on data acquired with measurement of selected fragments of casts, executed on laser profile measurement gauge MicroProf of the FRT company. Measurements were executed for 8 samples divided on two groups.

First of them was the starting material, in state directly after casting without any processing of surface. Material made up second group after apply an oxide layer by galvanic method.

Investigations were carried out on EN AC-AlSi12(b) as well as EN AC-AlSi9Cu3(Fe) alloys. For both EN AC-AlSi12(b) as well as EN AC-AlSi9Cu3(Fe) alloys, high pressure and sand casting was used. The chemical composition of these alloys is showed in table 1.

Four elements were anodized:

- EN AC-AlSi12 high pressure cast alloy,
- EN AC-AlSi12 sand cast alloy,
- EN AC-AlSi9Cu3(Fe) high pressure cast alloy,
- EN AC-AlSi9Cu3(Fe) sand cast alloy.

2.2 Anodization process

Table 1.
Concentration of alloying elements in EN AC-AlSi12(b) and EN AC-AlSi9Cu3(Fe) alloys

Alloy	Elements concentration, mass %						
	Si	Mn	Fe	Zn	Mg	Cu	Al
AlSi12(b)	12,5	0,5	0,6	0,1	0,05	0,05	Rest
AlSi9Cu3(Fe)	9,5	0,5	0,9	0,5	1,5	3,0	Rest

Table 2.
Anodizing parameters

Parameter	Value
Electrolyte	H_2SO_4 with a concentration 295÷315 g/l
Temperature	-4 ÷ 2°C
Pulsating current	2 A/dm^2 during 0,25 s 1 A/dm^2 during 0,1 s
Concentration of aluminum ions	6÷9 g/l

To determine the influence of a kind of electrolyte onto homogeneity of pores in the oxides layer at the same conditions, the samples of EN AC-AlSi12 alloy were put under anodic treatment in the presence of the following electrolytes: 3% $H_2C_2O_4$, 4% H_3PO_4, 4% H_2SO_4, 3%CrO_3. The accuracy and preserving of the applied anodizing parameters are very important for the working process, the most important feature is to avoid of any over anodization (Fig. 5) which can disqualify and anodized part for further machining. A correctly anodized part is presented on figure 4. Figure 3 shows a part before anodizing. A clear surface difference after and before anodizing can be state.

2.3 Microstructure investigation

- the material was cut on saw using the model Discotom-2 supplied by Struers.
- mounted in Resin 4 supplied by Struers using the press LaboPress-3 supplied by Struers
- ground on SiC paper size 80, 120, 180, 240, 320, 400, 600 using the grinding machine model Rotor-2 supplied by Knuth.
- polished using the polish machine model RotoPol-31 (with RotoForce-4, Multidoser and Rotocom) all supplied by Struers. Polishing were done according to Metalog A Methods by Struers.
- the microstructures investigation were done on the light microscope using the model BX60M supplied by Olympus. The microscope was equip with the camera model DP10 supplied by Olympus connect with the computer. The magnification range was choose for 500 to 1000 times. On the computer we used program “analysis” to capture and processing the photos.

2.4 Abrasive wear test

Abrasive wear test was performed using the tester model ABR-8251 supplied by TCD Tecnologi ApS.

The tests were done according to the specification by the standard ISO 8251. These are presented in the table 3

Wear resistance is expressed in mass loss [mg]. Each sample was weighed before and after the wear test. The test was repeated 5 times. Conditions for the abrasive wear tests ware presented in table 4

Table 3.
Abrasive wear test parameters

test parameters	
Load	4.9N (500g)
Slide velocity	40 cycles/min
Abrasive wheel steps	400 step/rotation
Worn area	12 x 30 mm

Table 4
Conditions for the abrasive wear tests

abrasive wear tests conditions	
Humidity	63%
temperature	23 C
Replicates	5

Fig. 3. Non anodized element made from the AC-AlSi12 aluminium alloy, produced by the Pressure Cast method

Fig. 4. Anodized element made from the AC-AlSi9Cu3 aluminium alloy, produced by the Pressure Cast method

Fig. 5. Overanodized element made from the AC-AlSi9Cu3 aluminium alloy, produced by the Pressure Cast method

3. Results and discussion

The alloys used in the presented investigation with two different but similar chemical composition were cast using two cast methods, namely the high pressure cast and gravitational sand cast. So the casting method is the most important factor in this study, which determines the quality of the anodized surface layer, some other important factor which also have influence on the resulting surface layer are the chemical composition of these alloys, the casting parameters as well as the attendance of layer.

Based on the metallographic examinations made on the optical microscope (Fig. 7÷12) it was stated that the anodic layer produced on pressure die castings and sand mould castings for both alloys does not reveal any discontinuity, which prevents from formation of pitting and the precipitated silicon (in the form of needles) contained therein influences on gain in abrasive resistance.

As shown in figure 6 the thickness of the oxide layer is bigger for the sand cast material compared the material produced by pressure cast, both for the AlSi9Cu3 as for the AlSi12 alloy. The layer is in this case about 5 times thicker. It is maybe due to that the dispersion of silicon crystals is lower and the particles are bigger. Bigger size of silicon phase particles may cause lower uniformity of the layer. On the other hand the layer thickness is lower for the pressure cast material. The layer is more uniform in case of the AlSi12 alloy.

In case of pressure cast better layer uniformity gives the AlSi12 alloy, however the thickness of the layer is bigger for AlSi9Cu3 alloy and the alloy has a lower layer uniformity.

For the sand cast the best results give the AlSi9Cu3 alloy, it has a lower layer thickness but the uniformity of the layer is better.

It can be state that both components made of AlSi9Cu3 alloy, cast in both sand mould and pressure die possess a comparable uniformity (Fig. 7 and Fig. 8) of the anodized layer. In the case of components made of AlSi12, their refined eutectic composition gives better uniformity of the anodized layer.

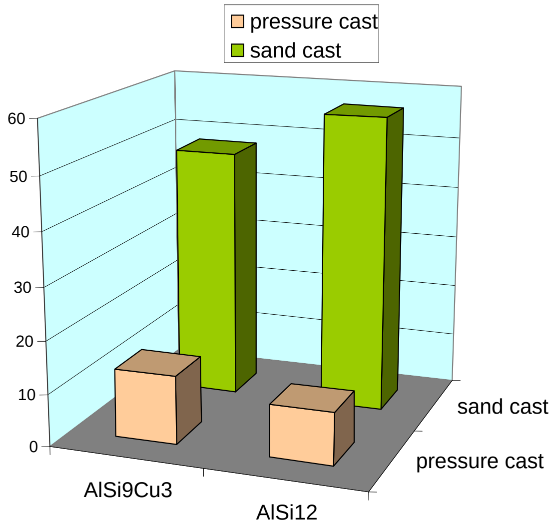

Fig. 6. Results of the anodic layer thickness measurement

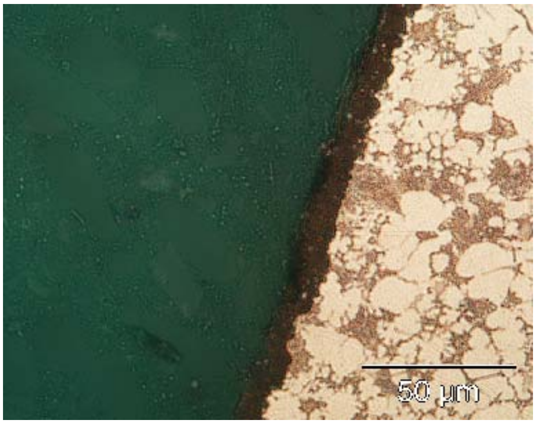

Fig. 7. Anodic alumina layer generated on the AlSi9Cu3 alloy, high pressure cast

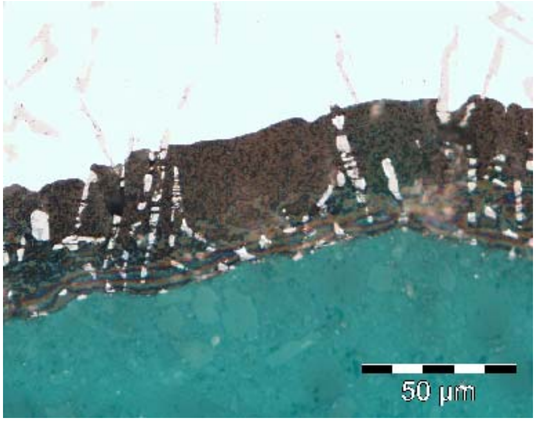

Fig. 8. Anodic alumina layer generated on the AlSi12 alloy, sand cast

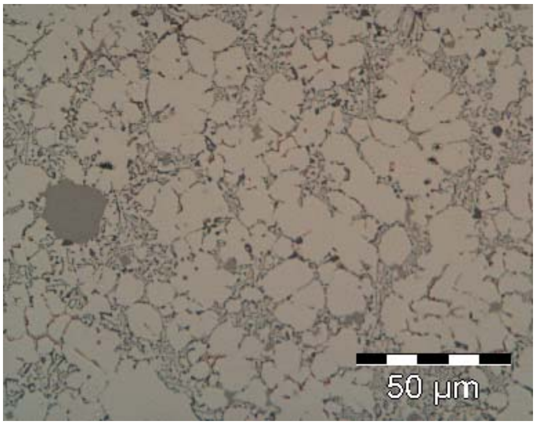

Fig. 9. Microstructure of the AlSi9Cu3 alloy, high pressure cast

Fig. 10. Microstructure of the AlSi12 alloy, sand cast

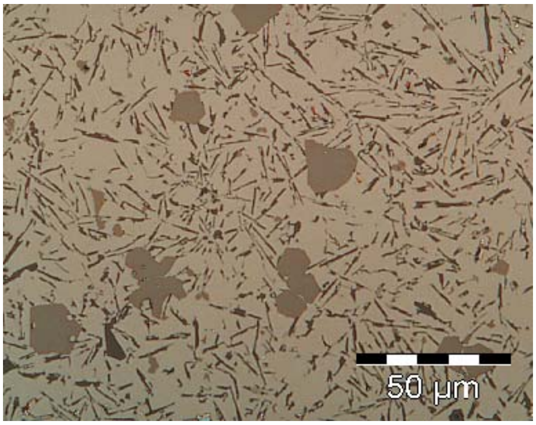

Fig. 11. Microstructure of the AlSi12 alloy, high pressure cast

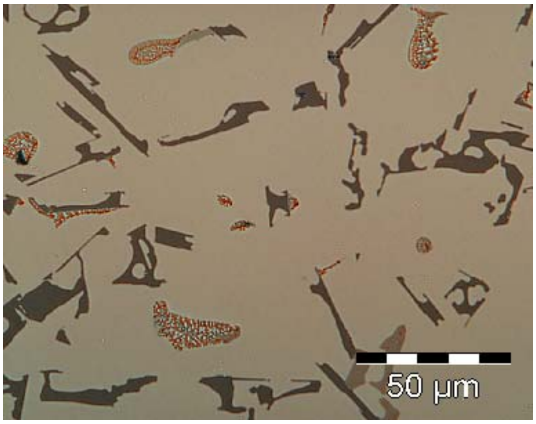

Fig. 12. Microstructure of the AlSi9Cu3 alloy, sand cast

It was stated in the result of the abrasive wear test that anodic treatment decreases abrasive wear. The best resistance to wear was achieved for great thickness of anodic layer (about 48 μm). A partial removal of the coat was observed for all casts produced in a pressure casting die, where thickness of the coat is lower (about 10 μm). The samples made of EN AC-AlSi12(b) alloy present greater loss in weight, which is caused by the fact that the testing place is located close to the electrode attachment (the layer in this place is probably thinner).

The results presented in table 6 indicate that anodized samples made of EN AC-AlSi9Cu3(Fe) alloy, cast into a sand mould, are characterized by a half lower loss in weight in comparison to the samples not anodized. In other cases the loss in weight decreases from 30 to 47%.

Table 5.
Mass loss in mg, registrated during wear test

alloy	Cast method			
	Sand cast		High pressure cast	
	unanodized	anodized	unanodized	anodized
EN AC-AlSi12(b)	14,0	10,2	18,7	10,0
EN AC-AlSi9Cu3(Fe)	14,7	7,3	17,6	10,9

4. Conclusions

The results of tests specified in Table 3 make it possible to determine clear out which of the tested alloys in combination with suitable manufacturing method (sand mould casting or pressure die casting) possesses the greatest abrasion resistance. The best results should be obtained for the combination of AlSi9Cu3 alloy with the sand mould casting as well as AlSi12 alloy cast in the pressure die. AlSi12 alloy cast in the sand mould and AlSi9Cu alloy cast in the pressure die present the lowest abrasive resistance.

The test results contained in the table allow to state that the anodised alloys both AlSi9Cu3 and AlSi12 indicate lower loss in weight in comparison with the non-anodised alloys. It can be stated that the casting method influence the abrasive resistance; sand mould cast alloys present the lower loss in weight during the carried out test, then they demonstrate the greater abrasive resistance.

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