Mechanics
Transport
Communications
Academic journal

ISSN 1312-3823 (print)
ISSN 2367-6620 (online)
volume 23, issue 3, 2025
http://www.mtc-aj.com **article № 2759**

ANODIZING DEFORMABLE ALUMINUM ALLOYS

Ilia Zumbilev
zumbilev@mail.bg

Technical University of Sofia – Branch Plovdiv,
BULGARIA

Abstract: *The aim of the present work is to establish a technologically optimal mode of heat treatment and hard anodizing for a suitable deformable aluminum alloy, in order to guarantee achieving a high-quality anode film.*

It was found that after heat treatment, aluminum alloy B95 has the highest core hardness and minimal deformation, but the surface hardness and the thickness of the anode layer are the lowest of the studied alloys. In thick-layer anodizing of aluminum alloy AD31, anode layer with the greatest thickness and surface hardness is obtained. After thick-layer anodizing of aluminum alloy AD31 at I = 4.5 A/dm for 90 min, the maximum thickness of 110µm and surface hardness of 445HV of the anode layer are obtained. With increasing the content of the alloying components Cu, Mg and Si, the thickness and microhardness of the anode layer decrease.

The most highly alloyed aluminum alloy B95 turns out to be with the lowest physical and mechanical parameters of its anode-oxide layer (60 µm thickness and 302HV0.1 microhardness) after thick-layer anodizing, which is due to the faster anode dissolution of the intermetallic compounds in it, compared to aluminum.

It was proved that during the process of heat treatment of aluminum alloys B 95, AB, AD31, AD35, the cooling media significantly affect their hardness and degree of deformation. The most favorable cooling medium for the studied aluminum alloys is water with a temperature of 80° C, at which the least deformation and relatively high hardness are obtained.

Key words: *hard anodizing, heat treatment, aluminum alloys*

1. INTRODUCTION

Aluminum alloys occupy a special place in modern machine building. Their rational use is one of the main objectives of every industry.

It is known that the surface of parts, made of aluminum and its alloys, is covered with a natural oxide coating, the thickness of which does not exceed 2 -5 µm. By applying anodizing to the aluminum alloys, the corrosion resistance of the resulting anode layer can be increased. At the same time, depending on the particular anodizing mode, additional qualities are added to the surface – increased hardness (200-500HV) and wear resistance, heat resistance, electrical insulation, high corrosion resistance and decorative appearance [1, 2, 3].

Oxide layers can be formed using chemical and electrochemical methods, but the chemical method cannot create thick anode layers with precisely defined properties.

Based on experimental data, maximum permissible limits and some quantitative ratios of the alloying components in deformable aluminum alloys have been established, which are used when selecting an optimal alloy for anodizing: Fe to 0,5%, Si 2-3%, Cu 1-2%, Mn 0,2 -0,8%, Mg to 0,7%, Zn 6 - 8%, Cu to 0,3% , Ti to 0,3% and for Zn/Cu from 2,75 to 3%, for Zn/Mg from 2,66 to 3%, for Cu/Mg - 0,75 - 1%, for Zn/Cu /Mg from 1,35 to 1,5 [2].

The structure of the aluminum alloy, obtained after heat treatment, is of particular importance for the quality of the anodized layer. The heterogeneity (inhomogeneity) of the base metal leads to obtaining a coating with low corrosion resistance, poor appearance (spots, mesh formations) and decreased mechanical properties (wear resistance and hardness). Therefore, by properly combining heat treatment of deformable aluminum alloys with their subsequent anodizing, a surface anode layer, meeting the requirements towards a specific part, can be obtained.

The aim of the present work is to establish a technologically optimal mode of heat treatment and hard anodizing for a suitable deformable aluminum alloy, in order to guarantee achieving a high-quality anode film.

2. METHODOLOGY OF THE STUDY

Samples with dimensions 230x80x20 mm, made of the following deformable alloys, were studied: B 95, AD 31, AD 35 and AB according to GOST 4794-74 and EN573-3:2009-08. Table 1 gives their chemical composition in %.

Table 1. Chemical composition of the studied alloys

Alloy grade GOST4784-97, EN573-3:2009	**Mg**	**Si**	**Cu**	**Mп**	**Zn**	**Fe**
AD 31, ENAB5063	0,6	0,52	0,066	0,035	0,14	0,14
AD *35* ,ENAB6082	1,04	1,20	0,1	0,52	0,11	0,22
AB -	1,09	1,07	0,42	0,48	0,18	0,28
B 95,ENAB7075	2,1	-	1.71	0,31	5,70	0,22

The test samples were subjected to heat treatment and then to thick-layer (hard) anodizing. The modes of the heat treatment are presented in Table 2, and the modes of the thick-layer (hard) anodizing - in Table 4.

Table 2. Modes of heat treatment

Material	**N of the mode**	**t hard. ° C**	**Time min**	**Cooling medium**	**t ageing ° C**	**Time h**
AD 31 ENAB5063	1	520	40	oil water t = 80° C water t = 40° C	170	14
	2	520	40		170	14
	3	520	40		170	14
AB	4	525	40	oil water t = 80° C water t = 40° C	170	12
	5	525	40		170	12
	6	525	40		170	12
B95 ENAB7075	7	470	40	oil water t = 80° C water t = 40° C	140	16
	8	470	40		140	16
	9	470	40		140	16
AD 35 ENAB6082	10	520	40	oil water t = 80° C water t = 40° C	170	14
	11	520	40		170	14
	12	520	40		170	14

The hardness of the samples was measured with a Brinell-Vickers HPO 250 hardness tester. The deformation of the test samples was determined based on data, collected by a MITUTOYO coordinate measuring machine. The samples, heat-treated under the modes 2, 5, 8 and 11 from Table 2, were subjected to thick-layer (hard) anodizing in a 20% solution of battery sulfuric acid at a temperature t = - 7° C with parameters of conducting the process, presented in Table 4.

The thickness of the anode layer was measured by means of two different devices at the same time: a microhardness tester "Leitz - Durimet" and a device "Isockops" 2.082.

3. RESULTS AND ANALYSIS

The conducted metallographic analysis of the anodized test samples shows the presence of an anode layer of varying thickness (Fig.1), which depends on the chemical composition of the aluminum alloys.

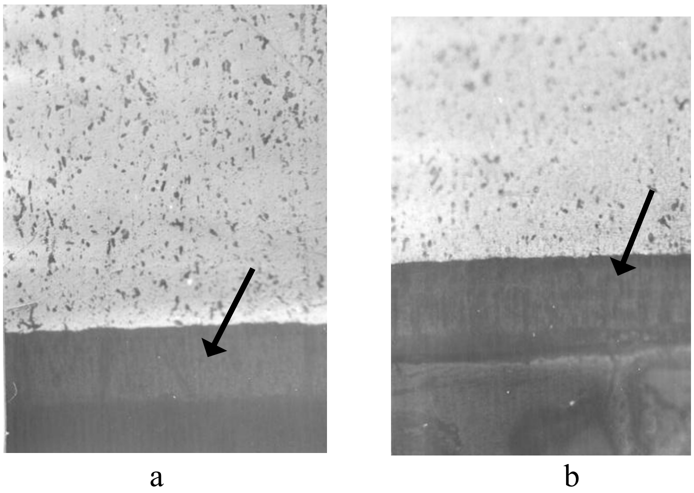
a b

Fig. 1. Microstructure of aluminum alloy after hard anodizing at I = 4.5 A/dm, time 90min: a-alloy AB, b-alloy AD31x 250

The modes and results from anodizing the test samples are given in Table 4.

From the heat treatment modes 2, 3, 5, 6, 8, 9, 11 and 12 (Table 2) it becomes clear that the most favorable cooling medium is water with a temperature of 80° C, which results in the smallest degree of deformation and relatively high hardness.

Table 3 illustrates that during the process of heat treatment of aluminum alloys B 95, AB, AD31, AD35, the cooling media significantly affect their hardness and the degree of deformation. This can be explained by the different cooling rates of the test samples in the selected cooling media. Having the lowest rate of cooling, oil produces minimum deformation but low hardness of the studied alloys. It can also be noted from Table 3, that under heat treatment modes 2,5,8 and 11, the most favorable combination of hardness and minimal deformation of the samples is achieved.

The predominant phase composition of the heat-treated aluminum alloys AB, AD 31 and AD 35 is α + Mg Si+Si, and for B 95 it is MgZn [1, 3].

Table 4 makes it clear that the most favorable parameters of hard anodizing for each of the three alloy types are, respectively, current density I = 4,5 A/dm^2 and process duration of 90 min. It was found that significantly better results are obtained with thick-layer anodizing of alloy AD31, compared to alloys AD35, AB and B95, under the same technical parameters and conditions of conducting the process.

Table 3. Hardness and deformation of the heat-treated sample bodies (results)

Material	**N of the mode from Table 2**	**Hardness** /HB	**Deformation /** mm
AD 31	1	50	0,1
AD 31	2	81	0,26
AD 31	3	82	0,38
AB	4	110	0,17
AB	5	110	0,28
AB	6	114	0,61
B 95	7	95	0,16
B 95	8	148	0,21
B 95	9	155	0,28
AD 35	10	59	0.13
AD 35	11	93	0,26
AD 35	12	98	0,45

The trend, that with increasing the content of Cu in aluminum alloys (from 0,066% in AD 31, through 0,10% in AD35 and 0,42% in AB, to 1,71% in B95), the thickness and microhardness of the anode layer decreases, is clearly seen. This can be explained by the lower copper content in AD31, in comparison with the other studied alloys.

Table 4. Modes and results of the process of anodizing the test samples

Material	Mode № from Table 2	S-sample dm^2	Current density $I, A/dm^2$	End voltage V	Cover thickness µm	Time min	HV0.1
AD 31	2	6	4	55	80	30	445
AD 31	2	6	5	57	90	60	445
AD 31	2	6	4.5	81	110	90	445
AB	5	6	5	87	68	60	400
AB	5	6	4.5	87	80	90	400
B 95	8	6	5	70	55	30	320
B95	8	6	4.5	75	60	60	302
AD 35	11	6	5	61	79	60	395
AD 35	11	6	4.5	82	92	90	410

Hard anodizing of aluminum alloys leads to the formation of the intermetallic compound $CuAl_2$, the amount of which is the smallest in AD31, compared to the rest of the studied alloys - B 95, AB and AD35. This compound dissolves much faster than aluminum, which is a prerequisite for obtaining thinner and more porous coatings under the conditions of hard anodizing. In addition, the higher content of Cu results in a less stable course of the anode oxidization process and an increase in the percentage of production scrapping. In this regard, the influence of Mg, Si and Mn is insignificant.

After hard anodizing of aluminum alloys, the anode layer, formed on their surface, consists of aluminum oxide /Al_20_3/, hydrated in the upper layers. The final product of the anodization is γ + Al203 - spinel type [1,3].

The most highly alloyed aluminum alloy B95 turns out to be with the lowest physical and mechanical parameters of its anode-oxide layer (60 µm thickness and 302HV0.1 microhardness) after hard thick-layer anodizing, which is due to the faster anode dissolution of the intermetallic compounds in it, compared to aluminum.

After mode 2 (Table 2) heat treatment of parts, made of aluminum alloy AD 31, and subsequent anodizing, production tests for reliability were performed. No visible changes were observed on the surface of the treated parts within the 1500 working hours, which completely meets the specified design requirements.

CONCLUSION:

It was established that after heat treatment, the aluminum alloy B95 is distinguished by the greatest hardness of its core and minimal degree of deformation. However, the surface hardness and thickness of its anode layer are the lowest, compared to the other studied alloys. After thick-layer anodizing of aluminum alloy AD31at I = 4.5 A/dm for 90 min, the maximum thickness of 110µm and surface hardness of 445HV of the anode layer are obtained. With increasing the content of the alloying components Cu, Mg and Si, the thickness and microhardness of the anode layer decrease.

REFERENCES:

[1] ALIEVA S. G., LLTMAN M. B., AMBARTSUMYAN S. M. et al., Industrial aluminum alloys, Reference ed. 3rd ed. rev. and supplemented edition, M. Metallurgy, 1989 (in Russian).

[2] TOLASHOV N. D., TYUKINA N. N., ZALIVALOV F. P., Thick-layer anodizing of aluminum and its alloys, M. Mashinostroenie, 1988 (in Russian)

[3] PENCHEV P., Handbook of Galvotechnics, fourth revised edition - TVR Print, Sofia, 2004 (in Bulgarian).