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INTERNATIONAL CONFERENCE of SCIENTIFIC PAPER
AFASES 2015
Brasov, 28-30 May 2015

THE BEHAVIOR OF AN AL_2O_3 COATING DEPOSITED BY PLASMA ELECTROLYTIC OXIDATION ON ALUMINUM ALLOYS AT HIGH TEMPERATURE REGIME

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Abstract: *Aluminum alloy present numerous advantages like high specific strength and diversity which recommend them to a high number of applications from different fields. In extreme environments the protection of aluminum alloys is difficult and requires a high number of requirements like high temperature resistance, thermal fatigue resistance and corrosion fatigue resistance. To obtain these characteristics, coatings can be applied to the surfaces so they can enhance the mechanical and chemical properties of the parts. This paper analyses an Al_2O_3 coating deposited by plasma electrolytic oxidation on an AA2024 aluminum alloy. The sample was subjected to a temperature of 500 °C and after that slowly cooled to room temperature. The sample was analyzed by electron microscopy and X-ray diffraction to determine the morphological and phase changes that occurred during the temperature exposure. To determine the stress level in the parts due to thermal expansion a finite element analysis was performed in the same conditions as the tests.*

Keywords: *Al_2O_3, PEO, AA2024*

1. INTRODUCTION

The purpose of this paper is to analyze the behavior of an AA2024 sample with an Al_2O_3 coating deposited by plasma electrolytic oxidation. The sample was subjected to high temperature. After the test the sample was analyzed by electron microscopy and X ray diffraction and also finite element analyses were done to determine the stress level that appears in the sample due to the different thermal expansion coefficients of the materials.

Yerokhin A. L. 1998, describes the fact that plasma electrolytic oxidation, also called micro arc oxidation represents a relatively new technique of surface modification which have a greater interest for achieving some ceramic oxide coating on Al, Ti and Mg alloys. [1-3]

The layer obtained by plasma electrolytic oxidation can enhance wear and corrosion properties as well as conferring other functional properties such as antifriction properties, thermal protection, optical and dielectric properties. Another used of plasma electrolytic oxidation is that of bond coating for other coating methods. [4]

Plasma electrolytic oxidation method is based on conventional anodic oxidation of metals with low density and their alloys in liquid electrolyte solution. This method works over voltage discharge which leads to micro plasma discharge. Plasma electrolytic oxidation method allows the formation of oxides coatings made of substrate material as well as more complex oxides containing elements present in the electrolyte. [5]

2. MATERIALS, METHODS AND INSTRUMENTATION

The deposition of the coating was done by plasma electrolytic oxidation spraying. After deposition, the sample was subjected to a temperature of 500°C for a period of two hours. The sample was cooled slowly in atmospheric air at normal temperature.

Electron microscopy and X ray diffraction were used to analyze the effects of the high temperature exposure on the sample. Before the analyses, the sample was cut, polishes and cleaned in ultrasonic bath.

In table 1 the parameters used for the elecrtolitic plasma oxidation are presented. Electrolyte solution used in deposition composed of: sodium metasilicate (Na_2SiO_3), sodium hydroxide (NaOH) and distilled water.

Table 1: Parameters of deposition

Technological parameters	Al_2O_3
Time (min)	2
Tension (V)	350
Intensity (A)	20

A finite element analysis was done to determine the mechanical stress that appears in the sample due to the thermal expansion of the materials. The mesh used in the finite element analyses is shouted in Fig 1. The mesh consisted of 50225 nodes and 25892 elements.

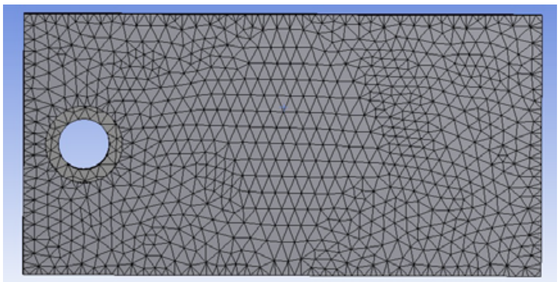

Fig. 1. The mesh used in the finite element analyses

3. RESULTS OF THE THERMAL EXPOSURE TESTS

In Fig. 2 a-b are presented images of the sample with an Al_2O_3 coating before and after the exposures to high temperature.

In Fig. 2 – a in cross section the microstructure of the layer obtained by plasma electrolytic oxidation after deposition can be observed. The layer obtained presents pores with different dimension and a very good compactness. Fig. 2 – b presents a SEM image in cross section of the layer obtained by plasma electrolytic oxidation after thermal exposure at 500ºC for two hours. In this case as well we can observe a compactness of the layer deposited. On the SEM image in cross section we can observe pores with different dimensions.

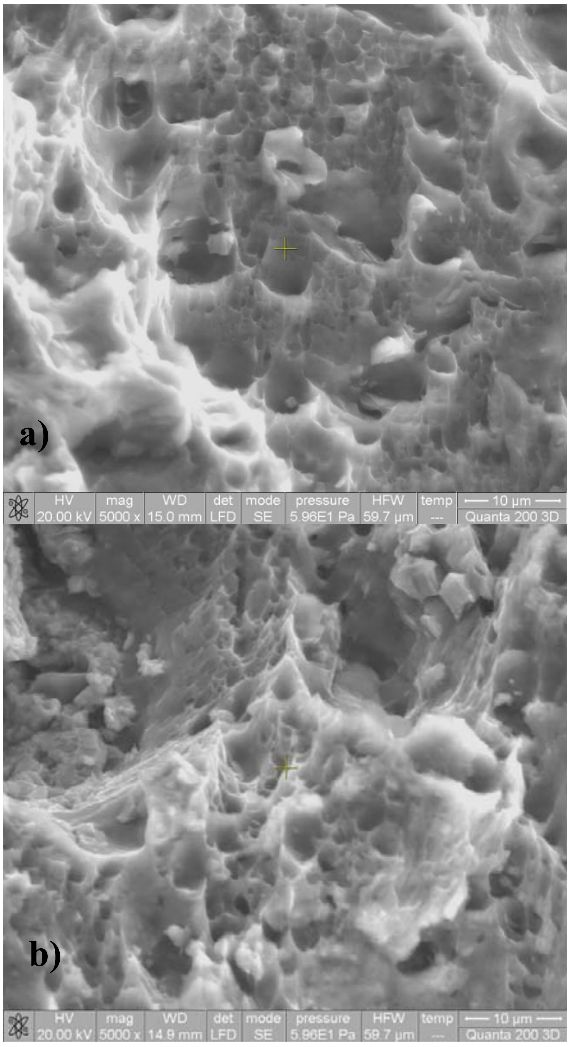

Fig. 2. SEM images at the magnification of 5000x of the Al_2O_3 coating: (a) before test, (b) after test

For the determination of the constituent phases of the layer obtained by plasma electrolytic oxidation we used X-ray diffraction method (Fig. 3.).

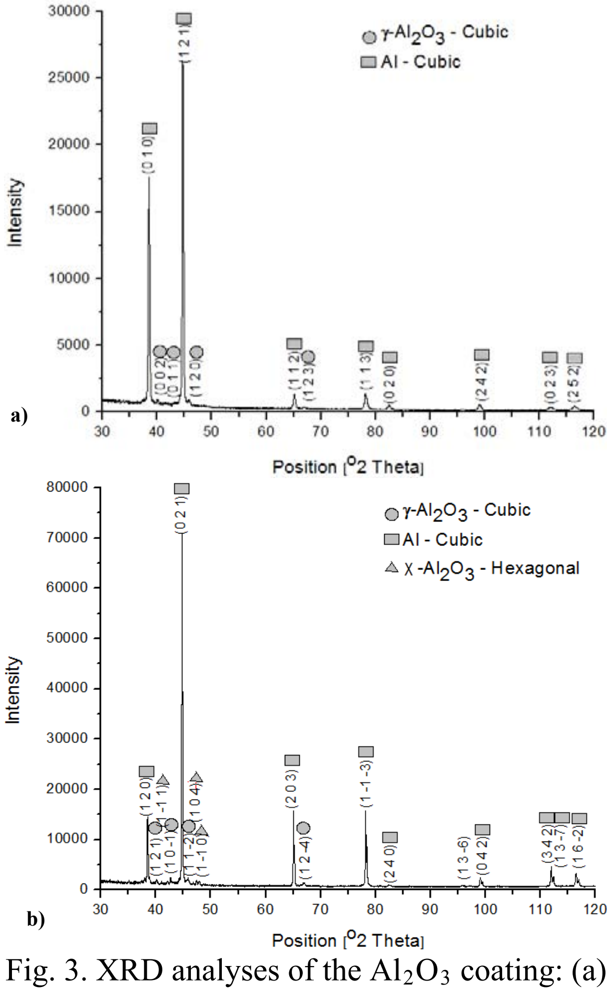

Fig. 3. XRD analyses of the Al_2O_3 coating: (a) after deposition, (b) after test

After plasma electrolytic oxidation deposition we can observe in the X-ray diffraction that the diffraction is made of one single phase namely is γ-Al_2O_3. The intensity peaks which determine Al phase on the surface is due to X-ray penetration through the coating, due to the pores obtained in coating after deposition. This Al phase is identified from the base material.

After thermal exposure at 500°C the Al phase which appears on the diffraction due to X - ray coating penetration remains unchanged, crystallizing in cubic system. In the case of the γ-Al_2O_3 phase, as well, in it unchanged the cubic system. Due to oxidation after thermal exposure appeared on the surface a new phase χ-Al_2O_3 which crystallized in hexagonal system. The picks increased in intensity due to the coating being sintered.

Maximum equivalent stress appears on the clamping whole area. Its value is 252 MPa. On the surface of the sample the maximum equivalent stress is 200 MPa. In the cross section of the sample we can that the base material is less solicited mechanical, and the tension distribution on the surface is extended in all layer body (Fig. 4.).

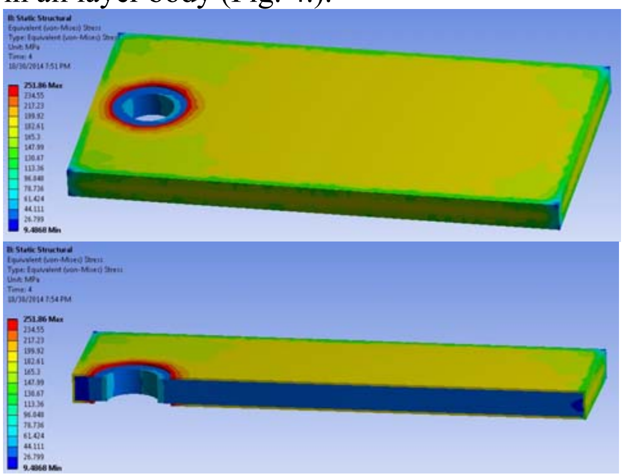

Fig. 4. Tensile stress distribution in the sample with an Al_2O_3 coating

The elastic strain distribution is presented in Fig. 5. The maximum value of the elastic strain on the clamping hole is 0.78%, and on the rest of the surface layer is 0.73%.

In Fig. 6 the plastic deformations of the sample is presented. The value of the plastic deformation is very small in the coating layer, except for clamping hole area where the value is 0,3%.

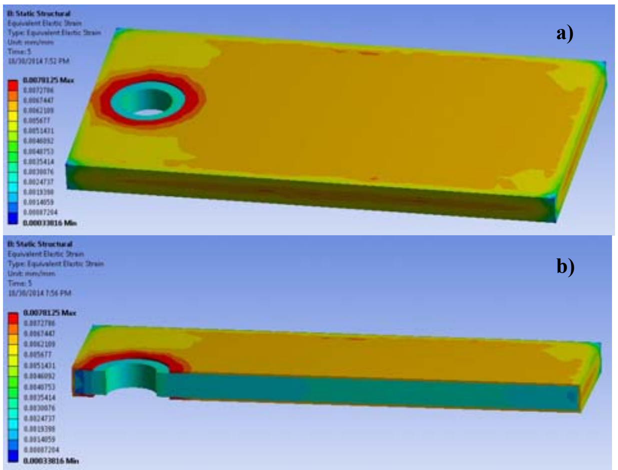

Fig. 5. Elastic strain distribution in the sample with an Al_2O_3 coating

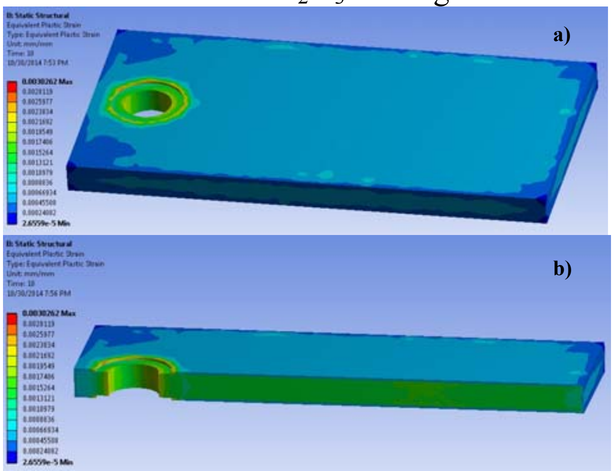

Fig. 6. Plastic deformations in the sample with an Al_2O_3 coating

Fig. 7 presents the total deformation which appears in the sample. The maximum value of the total deformation is 0.62 mm.

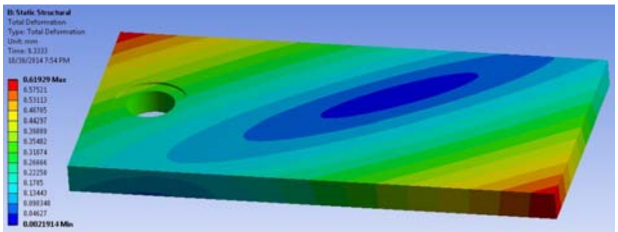

Fig. 7. Total deformation in the sample with an Al_2O_3 coating

5. CONCLUSIONS & ACKNOWLEDGMENT

The exposure of the sample with a coating of Al_2O_3 obtained by plasma electrolytic oxidation at a temperature of 500°C produced a higher level of compactness of the deposited coating. The volume of the pores and the thickness of the splats interfaces decreased.

This work of Pintilei Geanina Laura was supported by the strategic grant POSDRU/159/1.5/S/138963 - PERFORM, co-financed by the European Social Fund – Investing in People, within the Sectoral Operational Programme Human Resources Development 2007-2013.

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