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THE INFLUENCE OF AL_2O_3 DEPOSITED COATING BY PLASMA ELECTROLYTIC OXIDATION TO THE BEHAVIOR OF AN ALUMINUM ALLOY SUBJECTED TO MECHANICAL SHOCK

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Abstract: *This paper analysis the resilience of an Al-Cu-Mg aluminum alloy subjected to shock loads and the way how a coating can improve its behavior. For improving the behavior was used plasma electrolytic oxidation deposited of Al_2O_3 coatings. The samples without and with coating were subject to mechanical shock to determine the resilience of the materials. The cracks propagation was investigated using the QUANTA 200 3D DUAL BEAM electron microscope. To highlight the physical phenomenon that appears in the samples during the mechanical shock, explicit finite element analysis were done using Ansys 14.5 software.*

Keywords: *Charpy test, Al_2O_3, AA2024*

1. INTRODUCTION

Electrolytic plasma oxidation, also called micro-arc oxidation, is a relatively new technique of surface modification. This method has a greater interest for achieving some ceramic coatings oxides on Al, Ti and Mg alloys. [1-5]

The layers obtained by micro arc oxidation can enhance wear resistance and corrosion properties as well as conferring other functional properties such as anti-friction, thermal protection, optical and dielectric properties. [6-8]

This research analyzes the influence of PEO coatings on aluminum alloys related to the energy needed to fracture the materials and also on the nature of the fracture. One type of coating was considered in this paper and a comparison was made relating to a sample without coating. To highlight the results, electron microscopy was used. This was achieved with the QUANTA 200 3D DUAL BEAM electron microscope.

2. MATERIALS AND METHODS

The impact test was done using the Charpy method on six samples, three samples with Al_2O_3 coating deposited by plasma electrolytic oxidation and three samples without coating.

After the tests, the samples were analyzed using the QUANTA 200 3D DUAL BEAM electron microscope to determine the fracture profile and the influence of the mechanical shock on the deposited coating.

A finite element analysis was done using the Explicit Dynamics module from Ansys 14.5 to determine the stress distribution inside the materials during the impact test. In Fig. 1

the meshes used for the finite element analysis are presented.

The mesh for the base material sample was composed of 2521 nodes and 3122 elements. The model with Al_2O_3 coating was composed of 6759 nodes and 7583 elements.

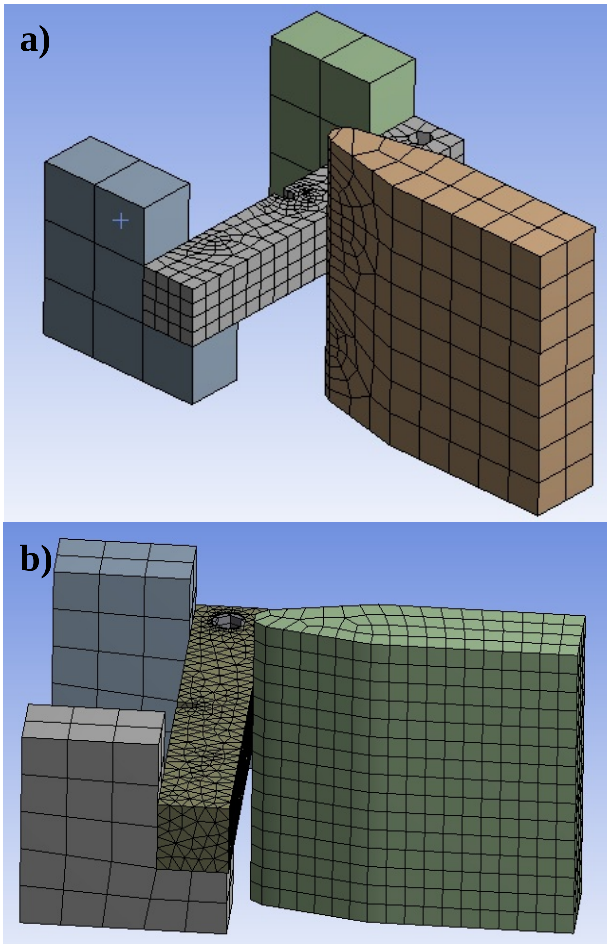

Fig. 1. The meshes used in the finite element analyzes: (a) sample without coating, (b) Al_2O_3 electrolytic plasma oxidation

Electrolyte solution used in deposition is composed of: sodium metasilicate (Na_2SiO_3), sodium hydroxide (NaOH) and distilled water.

3. RESULTS OF THE CHARPY IMPACT TESTS

3.1. The results for the samples without coating. In Fig. 2 SEM images of the sample without coating after the impact test can be observed. We can observe in SEM images that the fractures an irregular profile with large plastic deformation. This indicates that the sample suffered a ductile fracture due to mechanical shock. The energy needed for the fracture in impact test had the recorded values of: 188.7 J, 189.3 J and 189.23 J. It can be determined that the average plastic deformation energy for all three samples without coating is 289 J.

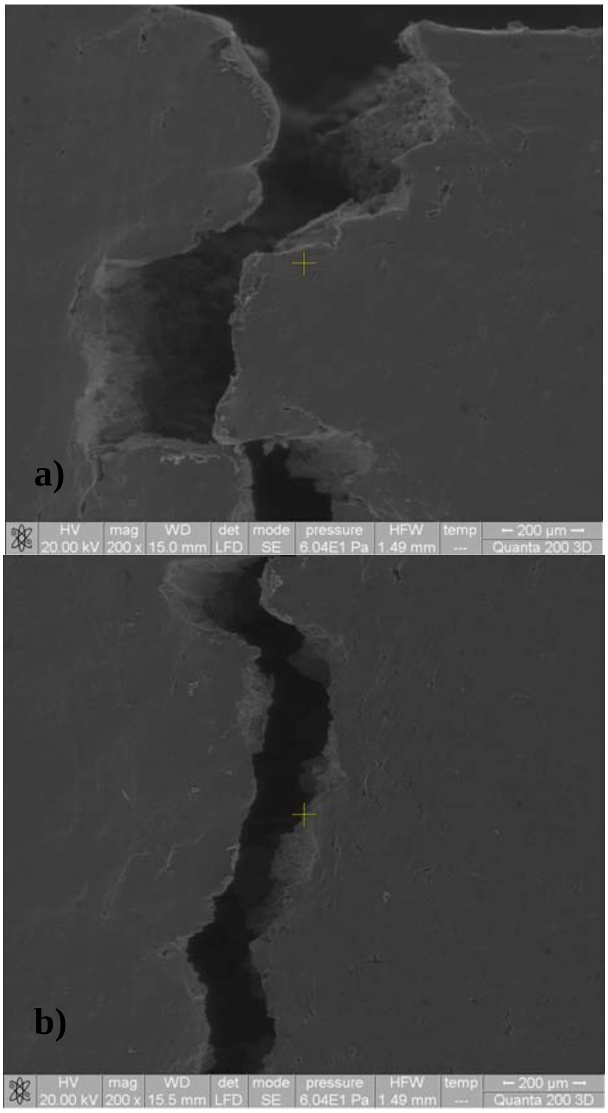

Fig. 2. SEM images for the 2024 sample: (a) the fracture propagation 200x, (b) cracks propagate in the material 200x

In Fig. 3a rezults after cracks propagation in samples are presented. The maximum stress which appears in the contact area with the supports is 303MPa. High value of stress is due to crushing of the material in that region. Maximum value of the stress which appear in contact area with pendulum is 281.4 MPa. We can observe that the crack is initiated in the U notch and its propagated to contact area with pendulum. Fig. 3b shows results at the end of the simulation and it can be observed that the sample was brocken. The profile of the fracture in simulation is similar with the samples obtained experimentally.

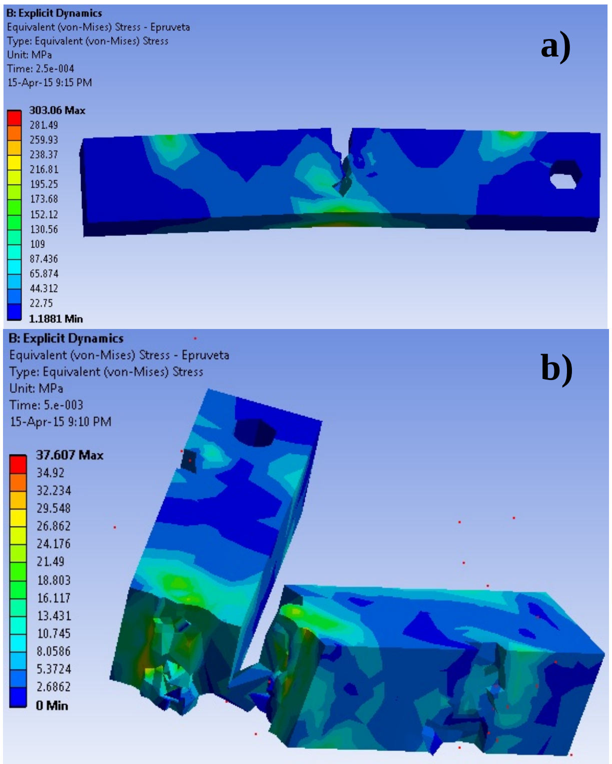

Fig. 3. The stress distribution in the impact test for the sample without coating: (a) the fractures initiation, (b) at the end of the simulation

3.2. The results for the samples with Al_2O_3 coating obtained by electrolytic plasma oxidation. In fig. 4 SEM images of the samples with Al_2O_3 coating after impact test are presented. The SEM analysis revealed that the sample fracture is similar with the samples without coating. The profile of the fractures is irregular and material base suffered big plastic deformation during the test. These results indicate that the samples suffered a ductile fracture. In the impact zone with the pendulum, in the area in contact with stands and in the area of U notch the coating exfoliated due to contact fatigue and intensive bending. The energy needed from the fracture of the samples had a value of 190.07 J, 191.37 J and 194.08 J. The average energy value for these samples is 192.08 J.

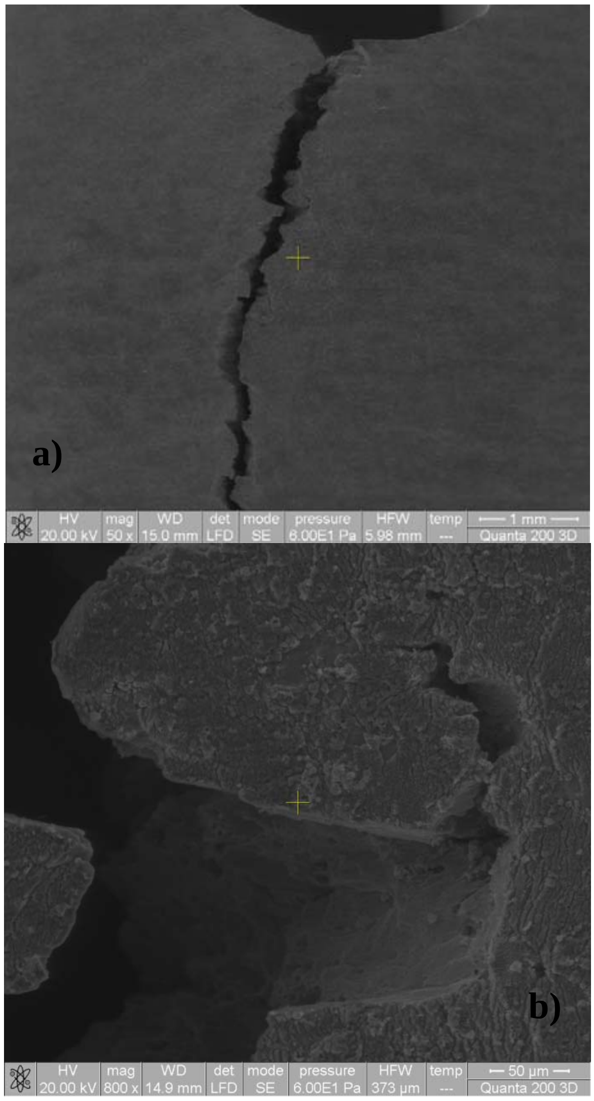

Fig.4. SEM images for the sample with Al_2O_3 coating: (a) the fracture propagation 50x, (b) cracks propagate in the material 800x

The EDAX analysis presented in fig. 5 showed a good adherence between Al_2O_3 coating and aluminum alloy material base. In this analysis we can observe only chemical elements of the coating.

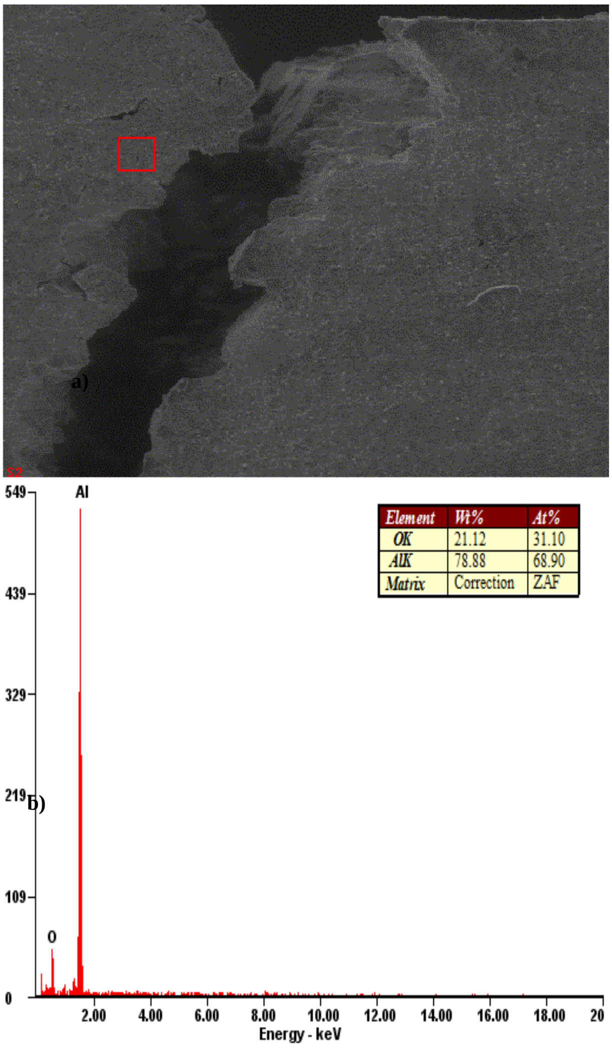

Fig. 5. The EDAX analyses for the sample with Al_2O_3 coating: (a) on the surface with the remained coating, (b) on the exfoliation surface

Maximum tensile stress achieved appears shortly before fracture initiation and has the value of 282 MPa (Fig. 6a). This value of the tensile occurs on the surface of the U notch. In the area of the notch with Charpy pendulum the coating exfoliated.

In Fig. 6b equivalent stress distribution to the end of the simulation is presented. The profile of the samples confirms the results obtained experimentally regarding its ductile fracture of it. On the samples we can observe area in which the layer presents coating exfoliation on the base material. But this exfoliation is not completed.

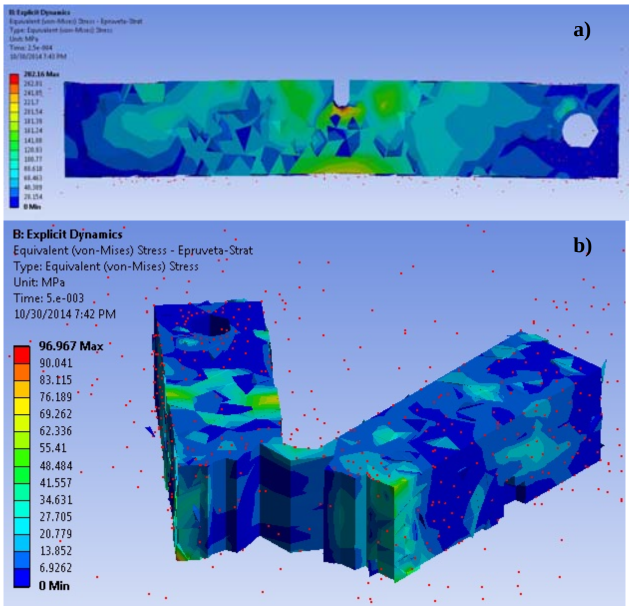

Fig. 6. The stress distribution in the impact test for the sample with Al_2O_3 coating: (a) the fractures initiation, (b) at the end of the simulation

4. CALCULATIONS OF THE KCU RESILIENCE

The results of the resilience test are defined by the ratio between the energy needed to fracture and the sectional area in the notch.

The average thickness of the Al_2O_3 coating is 173 μm. The measurement of the Al_2O_3 coating is presented in Fig. 7.

The sample with an Al_2O_3 coating has a resilience average value of 618.081 J/cm^2 and the sample without coating has a calculated average value of the KCU resilience of 630.233 J/cm^2.

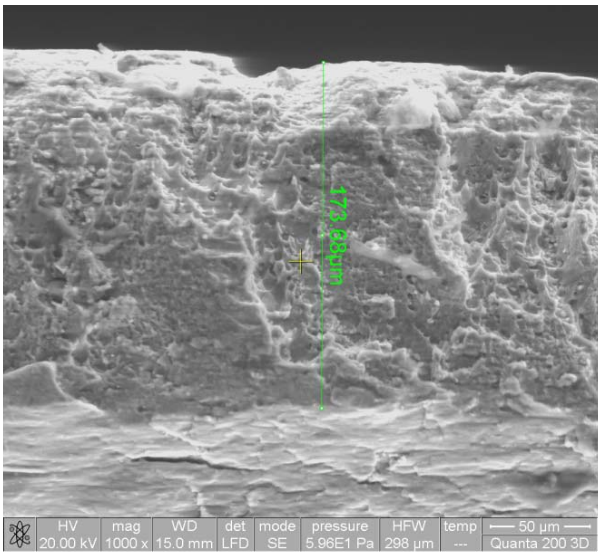

Fig. 7. Measurements of the coatings tightness Al_2O_3 PEO coating

5. CONCLUSIONS & ACKNOWLEDGMENT

Both results with finite element analysis and experimental tests confirm ductile fracture of the samples and a good adherence of Al_2O_3 coating layer with base material. Mechanical resistance required to break the sample was only 3.43% higher than the measured sample of AA2024.

Taking also in consideration the average of the coating tightness the variation of the KCU resilience is presented in Fig. 8.

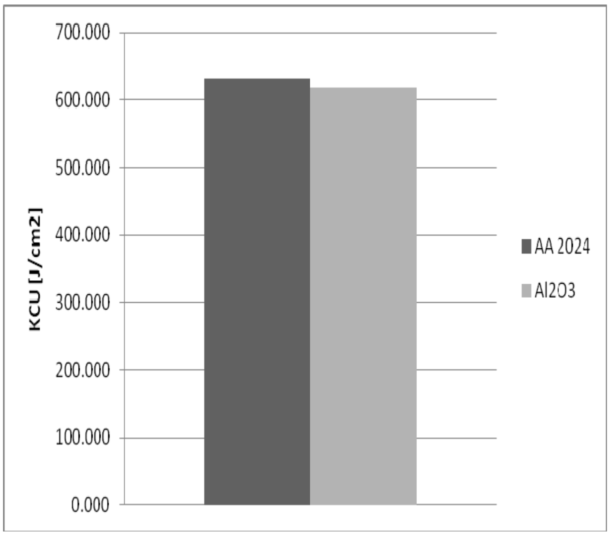

Fig. 8. The average KCU resilience values for the analyze samples

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