# СЕКЦИЯ №6
## SPACE INSTRUMENT MAKING

### Microarc Oxidation

Ananyeva E.S.
Scientific advisor: Ivanova V.S., Ph.D., Associate Professor
Tomsk Polytechnic University, 30, Lenin Avenue, Tomsk, 634050, Russia
E-mail: elena_girl_16@mail.ru

Microarc oxidation (MAO) is one of the most perspective aspects of superficial treatment modifications gaining wide recognition in majority of industries for forming of multipurpose ceramic-like coatings.

It is actual to production of serial high-technology equipment for implementation of microarc oxidation technics in the hypersonic field, allowing constructing new generation composites on a surface of valve metals and their alloys (titanium, aluminum, zirconium etc.) of various functionality with heightened physical-mechanical and service properties [1].

Air traffic strongly contributes to the increase in the global warming by emitting huge quantities of carbon dioxide (CO2) and other greenhouse gases in the atmosphere [2].

Aluminium or magnesium based alloys could efficiently replace iron base material for many parts of the aircraft structure or engine. However, these light alloys suffer from poor mechanical properties and are particularly sensitive to corrosion. Therefore such materials need specific surface treatments to improve their resistance and overcome their weaknesses [2].

As reminded in the CfP, in the aeronautic domain, 95% of Al-alloy made parts undergoes surface treatments.For aeronautic needs, anodising process is widely used to grow thin ceramic layers onto Al- and Mg surfaces thus improving wear resistance and corrosion protection of the as treated parts. In order to comply with industrial requirements for what concerns light alloys surface treatment, micro-arc oxidation (MAO) also known as plasma electrolytic oxidation (PEO) is a promising alternative to anodising. Indeed, this environmental friendly innovative technique allows ceramic layers to be grown getting the pieces high level mechanical properties and good corrosion protection in a single step processing [2].

The micro-arc oxidation (MAO) process has been examined on dense metals in a wide range of structures, but its application to metallic foams has not been systematically investigated. PEO is a plasma-assisted electrochemical surface treatment that is used to convert surfaces of light metals, e.g. Al, Mg and Ti, into hard and well-adhered oxide layers. The crucial problem in using these components are aluminium component’s poor surface hardness and wear resistance which limits its use in applications and reducing the lifetime of the substance [2].

Microarc oxidation (MAO) is such a method when a high-density current flows through the metal-electrolyte interface and there appear conditions, when microplasma discharges with high local temperatures and pressures appear on metal surface. As a result, a coating layer, consisting of oxidized forms of the elements of the base metal and electrolyte components, is formed. Depending on the mode of microarc oxidation and electrolyte composition it is possible to produce ceramic coatings with unique characteristics and a wide spectrum of application [3].

Coatings, made by microarc oxidation, are porous ceramic coatings of complex composition, produced as a result of oxidation of metal surface and invasion of electrolyte elements in the coating. Nanostructural non-metal coatings have a wide range of industrially important features: wear-resistance, corrosion-resistance, heat-resistance, low dielectric capacity, certain light-reflecting and light-absorbing features [3].

Dielectric features of coating depend on its thickness and application of infiltration of pores with different materials. Average voltage when coating is punctured is 600V. With filled pores – up to 2500V [3].

If necessary, coatings can have different light-reflecting and light-absorbing features. Reflecting capacity of MAO coatings reaches 80%. There are working methods of putting some basic colors: white, black, brown, grey, green and their tones [3].

**Advantages of MAO coatings**

Coatings produced with microarc oxidation method are ultrahard and resistant to various exposures. These coatings have perfect adhesion with surface of treated metal due to an intermediate layer between metal and coating [3].

Depending on purpose and future operational conditions of parts this method can produce coatings with thickness from fractions to hundreds micrometers that have several features in complex [3].

It is also possible to treat complex parts due to high dissipating ability of electrolyte and to form different coatings on one material [3].

Micro-arc oxidation (MAO) of metals is a complicated process combining concurrent partial process of oxide film formation, dielectric breakdown, dissolution of pre-existing film and anodic gas evolution. The probability of domination for any of these partial processes in the overall process depends on the nature of the substrate metal, the constituents and concentration of the electrolyte, as well as on the applied current density. Thus, MAO is an energy-consumption process, always accompanied by plasma chemical, electrochemical and physics chemical reactions in the micro-arc discharge channels. Under those circumstances the subject of current efficiency becomes very important. The primary objective of this study is to evaluate the oxide film growth efficiency during MAO process. A series of experiments based on different operating conditions have been performed and the current efficiency has also been calculated. The possible reasons leading to the low current efficiency have also been evidenced as anodic oxygen gas evolution, metal anodic dissolution and chemical dissolution of pre-existing oxide films in the electrolyte. Among these reasons oxygen gas evolution associated with electronic current during sparking is considered to be the dominating one for the low current efficiency, and the factors contributing to formation of oxygen bubbles have also been categorized [4].

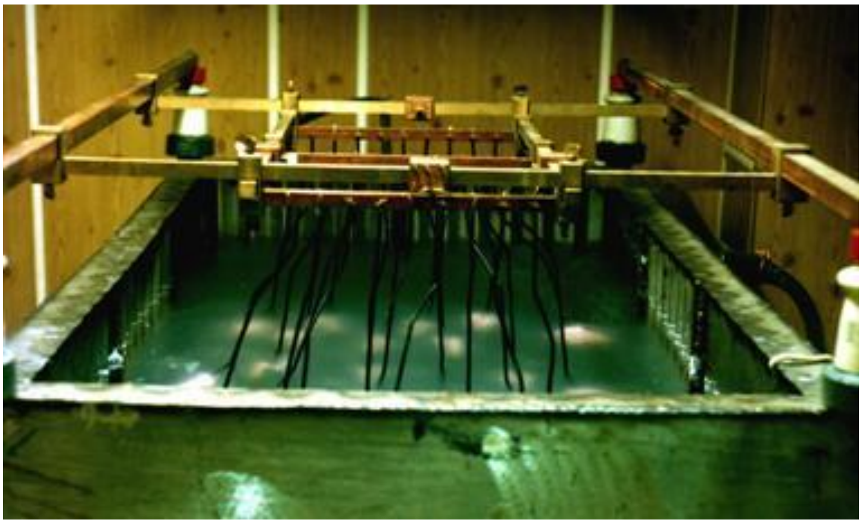

Figure 1 – Process microarc MAO

During the early stage of MAO treatments, microarc covers the anode, and then thin oxide films form at the anode surface. The localized liquid phase near pores in oxide films is rapidly solidified inside the electrolyte at ∼50 °C, and thus the porous structure can be maintained. The microarc always occurs at the structurally weak regions, such as cracks and pores, so partial melting phenomenon occurs at the pore regions. As MAO treatment time period increases, the pore structure could be destroyed due to the repeated microarcing [5].

## Conclusions

Figure 2 – The piston of the EM-100 engine with the MDO-layer

As a conclusion, the MAO process with its advantage is one of the most common coating methods for the light weight materials. Its corrosion resistance, thermal endurance, high hardness value makes this method more important for aerospace and automotive industries. If the investigations on this method come with solution for the expense of the process, it will be the best method for coating light materials [6].


References:

1. S. Abbasi, F. Golestani-Fard, M.M. Mirhosseini, A. Ziaee, M. Mehrjoo. Effect of electrolyte concentration on microstructure and properties of micro arcoxidized hydroxyapatite/titania nanostructured composite [Электронный ресурс] – Iran – URL: http://www.academia.edu/7384765/Effect_of_electrolyte_concentration_on_microstructure_and_properties_of_micro_arc_oxidized_hydroxyapatite_titania_nanostructured_composite, режим доступа - свободный.

2. Corrosion PROtective Coating on Light Alloys by Micro-arc oxidation [Электронный ресурс] – URL: http://cordis.europa.eu/result/rcn/155813_en.html, режим доступа – свободный.

3. About MAO metod [Электронный ресурс] – URL: http://manel.ru/en/method, режим доступа – свободный.

4. Hongfel Guo, Maozhong An, Shen Xu, Huibin Huo. Formation of oxygen bubbles and its influence on current efficiency in micro-arc oxidation process of AZ91D magnesium alloy. [Электронный ресурс] – Chine – URL: http://cat.inist.fr/?aModele=afficheN&cpsidt=16939967, режим доступа – свободный.

5. Young-Keun Shina, Won-Seok Chaeb, Yong-Won Songc, Yun-Mo Sungd. Formation of titania photocatalyst films by microarc oxidation of Ti and Ti–6Al–4V alloys [Электронный ресурс] – URL: http://www.sciencedirect.com/science/article/pii/S138824810600018X, режим доступа – свободный.

6. Cenk Mısırlı, Mümin Şahin and Ufuk Sözer. Effect of Micro Arc Oxidation Coatings on the Properties of Aluminium Alloy [Электронный ресурс] – Turkey –
URL: http://www.intechopen.com/books/aluminium-alloys-new-trends-in-fabrication-and-applicationcs/effect-of-micro-arc-oxidation-coatings-on-the-properties-of-aluminium-alloys, режим доступа – свободный.