

A GENERAL OVERVIEW OF THE MAO PROCESS ON ALUMINUM ALLOYS

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Abstract

Nowadays, materials which are weight saving are becoming increasingly important every day. Because of this situation, design engineers in aerospace and automotive industries are trying to make more extensive use of materials such as titanium, magnesium, aluminum and their alloys but because of their poor resistances, they need some treatments to increase their resistances by which they lost some of their durabilities.

In this paper, as one of the most common treatment process of aluminum alloys, Micro Arc Oxidation (MAO) is studied with its advantages and disadvantages more and more the problems that occur during the process are also studied.

Keywords: Oxidation, micro-arc, micro-arc discharge Oxidation, ceramic coating.

INTRODUCTION

It is certain that with every passing day demand for lighter, more durable, recyclable and replaceable materials are increasing for economical and technical considerations. That is why aluminum and its alloys are becoming more and more usable every day but the poor surface hardness and wear resistance are reducing the lifetime of the components that are made from them and limits its use in applications.

Previous treatments on aluminum such as anodising and thermal spraying have suffered from the low load support from the underlying material and insufficient adhesion. Also some coated aluminum alloys can achieve high surface hardness but when it comes to practice they often show poor performance under mechanical loading.

On the other hand, by the means of MAO process which is also known as plasma electrolytic oxidation, spark anodisation or microarc discharge oxidation, with the combination of electrochemical oxidation and high voltage spark treatment, the engineering equipments which has excellent adhesive strength, friction, corrosion, wear, electrical and thermal properties are obtained [1].

In this study, by the sections below the process of the MAO, the importance of the electrolytic solution, the voltage values and the tests that are made after the MAO are studied and investigated.

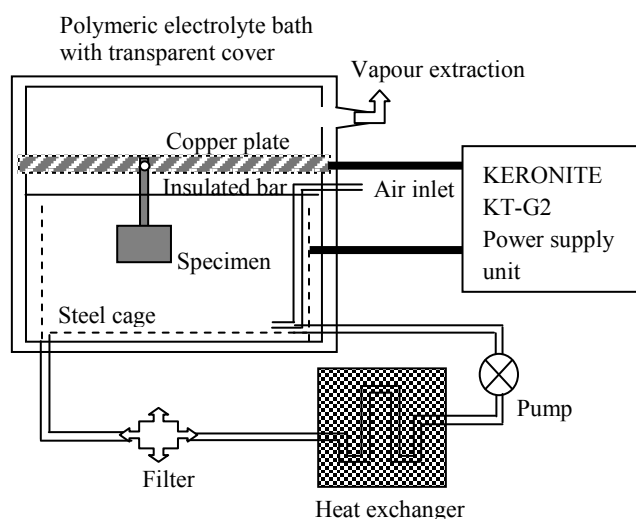


Fig.1. MAO Process[2]

THE PROCESS OF MAO

The process combines electrochemical oxidation with a high voltage spark treatment in aqueous electrolytic bath which also

contains modifying elements in the form of dissolved salts to be incorporated into resulting alumina coatings which are thick hard oxide ceramic coatings that are fabricated on aluminum alloys.

In this method, the metal used as anode is immersed in environmentally friendly alkaline electrolytes and the initiation of discharges is provided reaching the microarcing voltage at which the dielectric breakdown of the oxide film occurred. During MAO treatment, the electrolyte is pumped through a filter and subsequently a heat exchanger then introduced into the process chamber with micro bubbles oxygenating the electrolyte effectively. The oxide film proceeds via substrate metal oxidation and contribution of electrolyte additives such as phosphates and silicates into the coating structure. By other means, when high voltage is applied to the anode in an electrolytic solution, an oxide layer occurs. This is anodic oxidation. When the critical voltage degree is exceeded which is called dielectric breakdown, micro arcs starts to occur and this is called micro arc oxidation.



Fig.2. MAO Unit

In figure 2, a 20 kW -2 lab-scale MAO unit is shown. Generally, these equipments have a 25 liter electrolyte bath containing a micro bubble generator. The processing unit operates at 50 Hz constant frequency with maximum power output of 20 kW. It applies anodic voltages up to 200 V in order to maintain a constant current density during MAO treatment.

APPLICATION AREAS OF MAO

Basically, MAO process is used in 4 areas;

a.) Chemical Applications: At mid-level temperatures, it is resistant to strong acids and strong bases. That is why it can be used in chemical and food industries.

b.) Mechanical Applications: The Oxide layer formed by MAO process has a higher hardness than 1300 kg/mm². This high hardness value is one of the factors that increases sliding, abrasive and erosive wear resistances. More and more, the efficiency of the friction coefficient makes it useful in limited lubrication processes.

c.) Thermal Applications: Thermal inductivity of the oxide layer is lower than the other metal that is why they can be used to provide the same distribution of heat and also they can be used to increase thermal shock resistance.

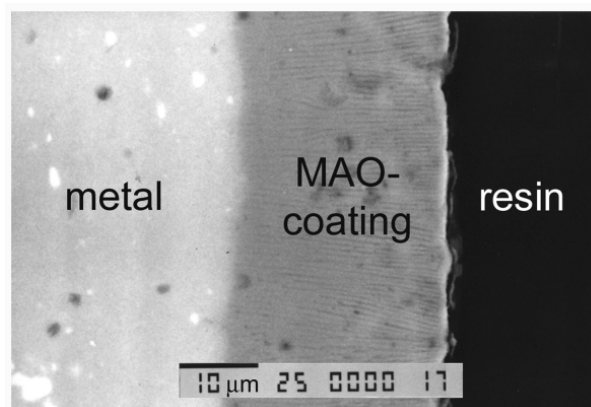


Fig.3. The change of element concentrations which are in the composition of hard coating along its thickness.

d.) Electric and Electronic Applications: It can be used as an insulator film on electric and electronic components. And also it is suitable for the hard coating of the inner areas (for conic, cavital or cylindrical areas).

THE ADVANTAGES AND DISADVANTAGES OF MAO COATINGS

The basic advantages of the MAO coatings can be shown as follows;

- No need for pre or post surface treatments.
- The electrolytes used in process are friendly to the environment.
- It can seem decorative by changing the color of the coating.
- We can obtain coatings which has high hardness value.

- e. Low friction coefficient surfaces can be obtained.
- f. The coatings have high wear resistance.
- g. Has high thermal endurance.
- h. Has high corrosion resistance.

Along with many advantages, MAO coatings have also some disadvantages. Firstly, with chosen parameters it requires a generator to increase up to 1000V voltage (nearly 1 MW). This high energy make the process dangerous according to the material size and material type. Also it is more expensive than the anodic oxidation process. More and more a high capacity cooler is needed to decrease the temperature of the solution. In addition to that in outer layers the coating is rough and fragile which makes the wear resistance decrease.

ANALYSIS OF THE COATINGS

The analyze of the coatings are made through some analyzing test. The basic analyze methods that are made for the MAO coatings are; SEM analysis, x-ray diffraction, impact test and hardness test.

The SEM analyses give us information about the surface of the coating. According to the coating time the thickness of the coating on the material will increase but in MAO process, at first the quality of the coating increases with the increasing coating time but after the derigueur time the quality of the coating decreases with increasing coating time that is why finding the optimized coating time has a vital importance in MAO coatings, with the help of SEM analysis we can see the amount of pores on the coating and this will aid us in understanding the quality of the coating.

X-ray diffraction test will help us understand the phase composition of the coating. Basically, these test will show the penetration depth of the coating in different angles and will give us some ideas about the composition of the coatings. X.Nie and Matthew A. used this test in angles 0.5° and 2.0° respectively and found out the that in different depths of both porous and dense layer the coating composition remains same in mixture of both $\alpha\text{Al}_2\text{O}_3$ and $\gamma\text{Al}_2\text{O}_3$. [3].

With different coating times which give us different coating thicknesses and the state of

being polished or non-polished will give us different hardness and hardness will directly effect the quality of the coating. The Works on this subject tell us that after the coating thickness of $10\mu\text{m}$, the hardness of the coatings increase rapidly.

In impact tests, the balls are to be hit to the different coatings one after another and the crater diameters give us the cohesion failures of the coatings.

Generally, the craters in thin coatings are small and their diameter don't increase with the number of the impacts. Thick coatings has bigger craters according to the thin coatings and the craters diameters increase a little. But in intermediate coating thickness it is seen that there are some big craters and failures on the coating [4-5].

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 make this method more important for aerospace and automotive industries. If the investigations on this method comes with solution for the expense of the process, it will be the best method for coating light materials.

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