THE REPUBLIC OF TURKEY

BAHCESEHIR UNIVERSITY

EFFECTS OF MICRO ARC OXIDATION (MAO) COATINGS ON WEAR RESISTANCE OF HIGH PRESSURE DIE CAST ALUMINIUM ALLOYS FOR APPLICATION HYDRAULIC VALVES IN MECHATRONICS

Master's Thesis

RUKİYE SANİYE AKTAŞ

ISTANBUL, 2016

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PREFACE

First of all, I thank my father Ali Cengiz Aktaş, and also my mother Nurhanım Aktaş for their educational supports for me throughout my life. I especially thank to my mom for bringing me into the world and taking care of during my life. I always thank my sisters and my friends for being with me and their help.

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İSTANBUL, 2016 Rukiye Saniye AKTAŞ

ABSTRACT

EFFECTS OF MICRO ARC OXIDATION (MAO) COATINGS ON WEAR RESISTANCE OF HIGH PRESSURE DIE CAST ALUMINIUM ALLOYS FOR APPLICATION HYDRAULIC VALVES IN MECHATRONICS

Rukiye Saniye Aktaş

MECHATRONIC ENGINEERING

Thesis Supervisor: PROF.DR. MUSTAFA OKTAY ALNIAK

JANUARY, 2016, 49 PAGES

Valve is among the most important elements in hydraulic systems. Hydraulic valves to determine the direction in which the hydraulic fluid, changes the desired direction, the circuit elements that control the fluid pressure and flow rate. The valves have improved with the development of technology. Programmable, manual and automatic valves that can be controlled remotely began to be produced. These valves, which allow the operation of a system without manual intervention, aircraft, and robotic systems, are used in the automotive industry and many different areas.

In this study, the wear on the hydraulic valves oxide coating on aluminum alloy is recommended as an alternative. The expected behavior of ceramic coated aluminum show, not as high corrosion resistance of ceramics of the biggest trends of stiffness and fatigue expectations.

In this study, the corrosion resistance of aluminum has tried to demonstrate these features winning will increase efficiency in the application should be high.

Ceramics The reason is intended to be a low cost alternative to ceramic materials featured quest. Micro-arc oxidation is one of the most effective surface treatments done to improve the corrosion resistance of aluminum alloys.

In this study, AA 6063 with surface micro-arc oxidation coating made of alloy and the coating thickness was determined by wear trends experiments. By this coating, resistance test results showed that low wear resistance of aluminum alloy has become quite high. This work describes the parameters affecting the wear of ceramic materials with information about wear rates applied to ceramics with aluminum coating thickness are given.

Ceramic coating is applied for the first time on forging or die cast aluminum valves. The valve design of experimental studies of the present study is considered to be a novelty.

Keywords: Coating, Hydraulic Valves, Micro-Arc Oxidation, Abrasion Tends, Ceramic

ÖZET

MEKATRONİK UYGULAMALARDA HİDROLİK VALFLERDE KULLANILMAK ÜZERE, YÜKSEK BASINÇTA ÜRETİLMİŞ ALÜMİNYUM ALAŞIMLARIN MİKRO ARK OKSİDASYON YÖNTEMİ İLE YAPILANMIŞ KAPLAMALARININ AŞINMA DİRENÇLERİNİN İNCELENMESİ

Rukiye Saniye Aktaş

MEKATRONİK MÜHENDİSLİĞİ

Tez Danışmanı: PROF.DR. MUSTAFA OKTAY ALNIAK

OCAK, 2016, 49 SAYFA

Hidrolik sistemlerdeki en önemli elemanlardan biri de valflerdir. Hidrolik valfler hidrolik akışkanın gideceği yönü belirleyen, istenildiğinde yönünü değiştiren, akışkanın basıncını ve debisini kontrol eden devre elemanlarıdır. Teknolojinin gelişmesiyle beraber valfler de gelişme göstermiştir. Programlanabilen, uzaktan kumanda edilebilen el yardımı ile çalışan ve otomatik valfler üretilmeye başlanmıştır. Bir sistemin çalışmasına olanak sağlayan bu valfler, uçaklarda, robotik sistemlerde, otomotiv sanayinde ve daha birçok farklı alanda kullanılmaktadır.

Bu çalışmada hidrolik valfler üzerindeki aşınmalara yeni bir alternatif olarak alüminyum alaşımı üzerine oksit kaplaması önerilmektedir. Seramik davranış göstermesi beklenilen kaplamalı alüminyumların, sertliklerinin korozyona karşı dirençlerinin ve yorulma eğilimlerinin seramikler gibi yüksek olması en büyük beklentidir.

Bu çalışmayla, bu özellikleri kazanan alüminyumların aşınma dirençlerinin yüksek olması gereken uygulamalarda verimi arttıracağı ispatlanmaya çalışılmıştır. Seramiğe bir alternatif bulunmak istenilmesinin nedeni maliyeti düşük seramik özellikli malzeme arayışıdır. Mikro ark oksidasyon yöntemi alüminyum alaşımlarının korozyon direncini arttırmak için yapılan en etkili yüzey işlemlerinden biridir.

Bu çalışmada AA6063 alaşımının yüzeyine mikro ark oksidasyon yönetimi ile kaplama yapılmış ve kaplama kalınlığının aşınma eğilimleri deneyler ile tespit edilmiştir. Deney sonuçları sonunda bu kaplama yöntemi sayesinde direnci düşük alüminyum alaşımının aşınma direnci oldukça yüksek hale geldiği tespit edilmiştir. Bu çalışmayla seramik malzemelerin aşınmasını etkileyen parametreler açıklanmış, alüminyum kaplama kalınlıkları ile seramik malzemelere uygulanan aşınma oranları hakkında bilgi verilmiştir.

Valflerde dövme veya basınçlı döküm alüminyum üzerine seramik kaplama ilk defa uygulanmaktadır. Bu çalışmayla ilgili yapılan deneysel araştırmaların valf tasarımında bir yenilik olduğu değerlendirilmektedir.

Anahtar Kelimeler: Kaplama, Hidrolik Valfler, Mikro Ark Oksidasyon, Aşınma Eğilimi, Seramik

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FIGURES

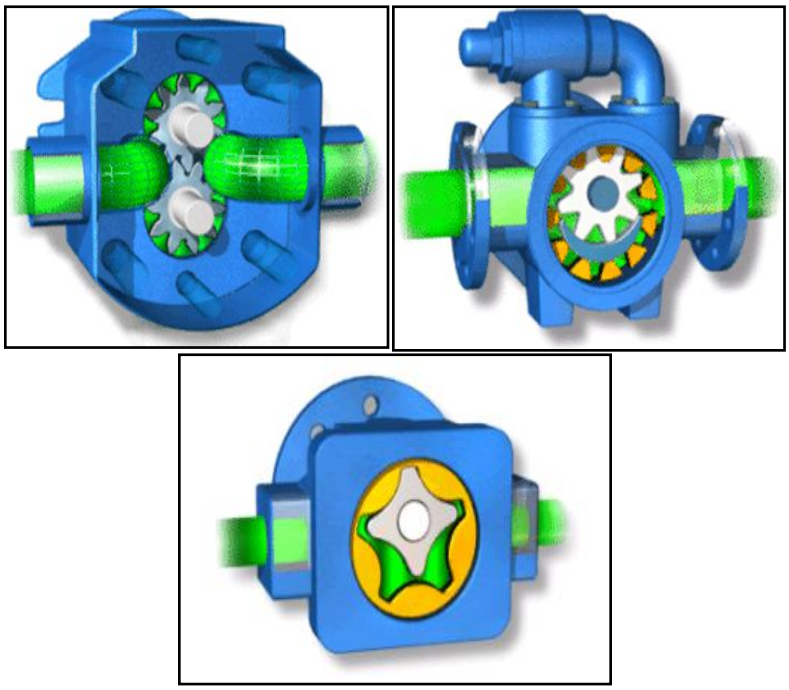
ABBREVIATIONS

MAO	:	Micro Arc Oxidation
PEO	:	Plasma Electrolytic Oxidation
SEM	:	Scanning Electron Microscope
XRD	:	X-Ray Diffraction Methods
ITU	:	Istanbul Technical University

1. INTRODUCTION

50 million valves are used every year on Turkey. Hydraulic valves are widely used in metal, polymer or plastic is made from. Aluminum alloy structures that are light metals alloys are divided by the nominal group. All these light metals in the major aerospace and aviation industry, used in the automotive and medical industries. These materials corrosion resistance made them more important in use as a component of internal combustion engines for instance cylinder blocks cylinder heads and pistons. [2] Water driven valves to decide the course in which the pressure driven liquid is fancied bearing that progressions are circuit components that control the liquid weight and stream rate. You can likewise see samples of water driven valves in Figure 1.1. The valves have enhanced with the improvement of innovation and programming has started to deliver corresponding valves that can be controlled remotely.

Figure 1.1: Hydraulic valves in mechatronics



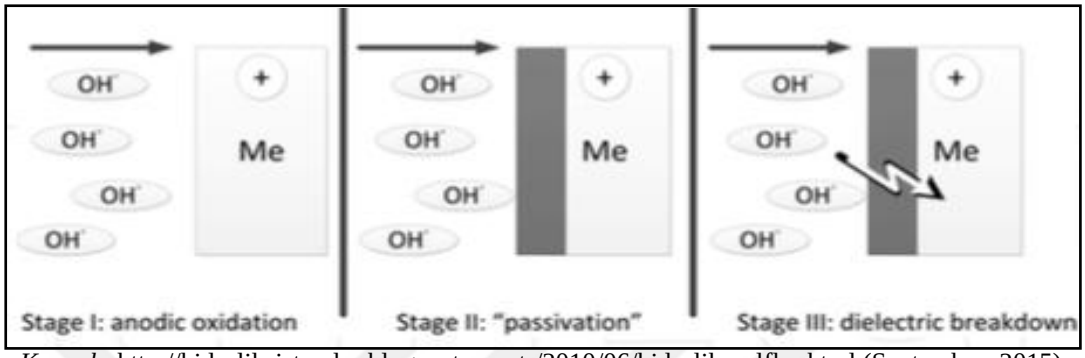
Kaynak: http://www.hidropaks.com.tr/uploaded/files/hidrolik%20valf.pdf - Hidrolik Valf Çeşitleri ve Çalışma Yöntemleri (September, 2015)

This valve, which allows the system to work without manual intervention, is used in aircraft and robotic systems. Speaking from the micro-arc oxidation method is one of the most effective surface treatment done to improve the corrosion resistance of aluminum alloys. In the literature, typically referred to as MAO. Together with MAO process, which is also known as plasma electrolytic oxidation, spark anodisation or micro-arc discharge oxidation, with the combination of electrochemical oxidation and high voltage spark treatment, the engineering equipments which have excellent adhesive, strength, friction, corrosion, wear, electrical and thermal properties are obtained. [3]

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. Micro-arc oxidation (MAO) is a cost effective technique of in-situ growth of ceramic coating on valve metals such as Al, Mg, Ti and their alloys.

Plasma electrolytic oxidation (PEO), also called micro-arc oxidation and ignition anodic oxidation process typically valve metals (Mg, Al, Ti, and a few others), and is considered to be a version anodizing or their alloys. Honestly, the essence of both anodizing and PEO is the production of oxide layers on a metal surface by the action of electricity in a convenient electrolyte. You can also see oxide layer from Figure 1.2. Layered oxide layer has a complex composition and includes various oxides of a base metal, alloy additives and species coming from the electrolyte. During anodizing the electrode potential of the electrochemical oxidation or other interactions around metal components of the electrolyte due to inclusion of some components, an oxide layer is formed.

Figure 1.2: Principle phases of an oxide layer development in the procedures of anodizing



Kaynak: http://hidroliksistemler.blogspot.com.tr/2010/06/hidrolik-valfler.html (September, 2015)

Abrasion resistance and metals used in the mechatronic applications based polymer is high. Considering behavior in high temperature resistance and hardness, fatigue resistance and wear resistance are high. Used in applications where effective due to erosion of these features. In this respect it is important to know the wear behavior. [3] Many of the corrosion resistance of the ceramic coating is very good. These properties mean that it can be used also for protection from corrosion by. Most of the cost of production due to the use of ceramic sector is not always preferable to less costly aluminum.

Figure 1.3 on commercially made of ceramic material used in many sectors, we can see the pieces. As it can see so much diversity. Here completely made of ceramic or ceramic able to see the product which causes corrosion resistance of coatings is preferred.

Figure 1.3: Variations in the ceramic material

Kaynak: http://www.metaluzmani.com/?page_id=312 (September, 2015)

Go to the multi-layer coating application in order to reduce the pores of the ceramic coatings are issues that the continuation of work on amorphous coatings. It has developed a lot during the folding process works. And developed this coating method are progressing through trials.

In our study, we aimed to achieve this by covering the micro-arc oxidation ceramic properties of aluminum alloys such as to show the wear resistance but very low cost number of ceramic products. Ceramic material, hard and very low because it has a coefficient of friction in the medium used for biomedical applications of diamond-like carbon material coated with the resistance potential chemical environment is too high. The utilities brittle ceramic materials. Chip takeoffs and transported. Under the surface of the ceramic material and surface cracks are formed. These cracks then occur combine ceramic material consisting of small chips [5].

Ceramic materials are susceptible to high compressive and tensile stress. Metal and polymer materials, they show plastic deformation before breaking across compressive stresses occurs.

However, the ceramic material of the plastic deformation shown there is only one condition. This condition is shown by plastic deformation of the ceramic material hydrostatic stress. However, this plastic deformation is quite small compared to metals and polymers [5].

A ceramic material, the temperature, by raising the melting temperature of the plastic deformation potential of 0.6 times the mobility of dislocations is increased. With high friction speeds, the reduction in strength is accompanied by a rise in temperature. However, ceramic materials increase in temperature until the metal plasticity with the increase does not cause frequent ductility. Ceramics show a behavior or semi-crunchy flakes. [5].

In ceramics, because of its low thermal conductivity, heat generated during rubbing can create a large thermal gradient and thus hot spots. If the ceramic material is cooled quickly, it creates hot spots substantially tensile stress and cracks may occur as a result thereof. As a result, large parts of the surface and would break the said increase in wear [5].

Ceramics are highly sensitive to strain rate. Therefore with increasing shear rate and the possibility of cracking increases with the friction heat in addition. This sensitivity; impact and the use of ceramic material against erosive wear reduces the agenda [5].

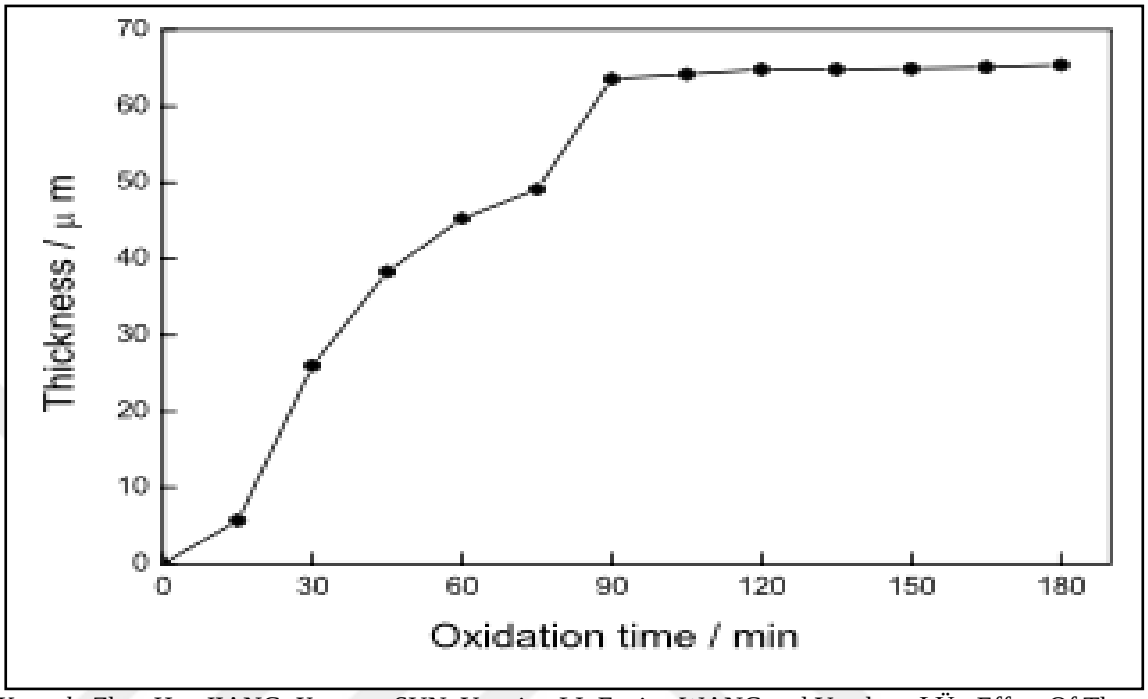
2. MICRO ARC OXIDATION TECHNIQUE

Small scale circular segment oxidation, anode-shimmer, is a standout amongst the most encouraging techniques for treatment of the material surface. Shapes the premise of the accompanying techniques: when a high-thickness current moves through the metal-electrolyte interface. Conditions are accessible when the anxiety at the interface gets to be higher than its dielectric quality, which brings about micro plasma releases with high neighborhood temperatures and weights. Layer structure covering with a layer that comprises of miniaturized scale curve oxidation covering procedures happening in the oxide layer. Concoction load move that occurred in the shower fluid, electron trade, bolted together give the arrangement of a solid covering. Thus the micro plasma oxidation administration and the electrolyte arrangement one can create earthenware coatings with special attributes and a wide application range.[8]

Al alloy surface micro-arc oxidation in thick, dense, riveted and new and is gaining attention as a unique way to create a layer of ultra-hard ceramic coatings. Also electrolytic micro plasma oxidation is called the MAO process, a high voltage substantially combines the electrochemical oxidation treatment. After the potential surpasses the basic values, the plasma release conditions emerge. As a result, oxide-based layers are formed on the anode surface, which have special properties different from those of conventional anodic films. During as many process simultaneously over the entire surface to be coated anode formed by plasma discharge. They exhibit improved mechanical properties of plasma sprayed ceramic coatings superior bond strength compared to coatings MAO synthesized in the anodic oxide coating process. Coatings, automotive, aerospace, medical and textile industries, in many applications, can be used. [8]

Micro-arc oxidation method of coating thickness on surfaces depends on time. Dwell time in the bath to oxidize the surface held with increasing coating thickness increases. As you can see by the time of coating thickness variation is shown in the graph on Figure 2.1.

Figure 2.1: Difference when the thickness of the coating



Kaynak: Zhao Hua JIANG, Xuetong SUN, Yanping LI, Fuping WANG and Yandong LÜ - Effect Of The Oxidation Time on Properties of Ceramic Coatings Produced on Tİ-6Al-4V by Micro Arc Oxidation

2.1 POSITIVE ADVANTAGES OF THE METHOD

Micro arc oxidation method and surface coating materials have certain advantages over other types of coatings while: [8]

a. The possibility of creating super-strength coatings with unique characteristics,
b. Obtaining several protecting characteristics in a complex,
c. Practically infinite service life of electrolyte,
d. The possibility of treating parts with a complex profile,
e. High scattering electrolyte capability (the coating is easily applied to openings and cavities),
f. No need of special preparation of a surface before applying a coating nor machining after that,
g. Production of various coatings on the same material.

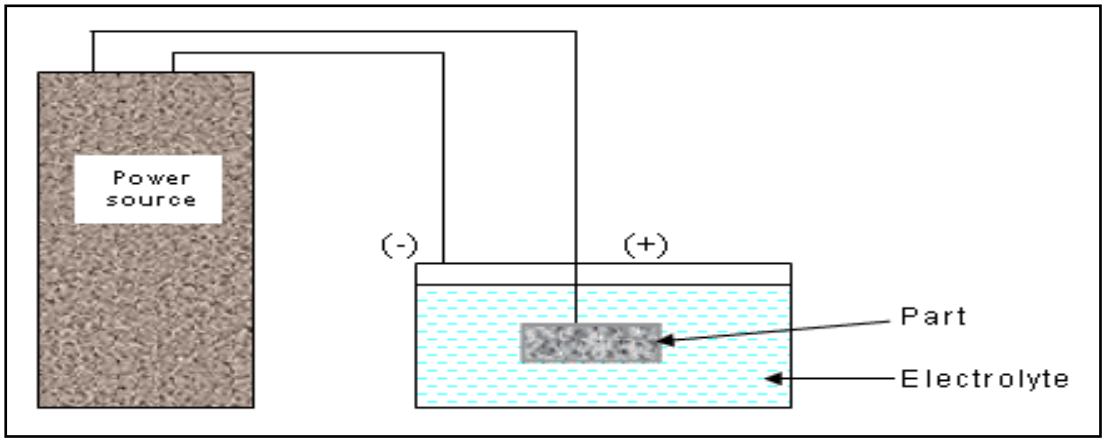
Figure 2.2: Practically infinite service life of electrolyte

Kaynak: https://en.wikipedia.org/wiki/Plasma_electrolytic_oxidation (September, 2015)

2.2 EQUIPMENT SETUP

In the general structure, Primitive trial setup, the MAO creation line incorporates power hardware, particular force sources showers for the arrangement of surfaces, treatment and washing a controller (if there should be an occurrence of a business generation) to move the suspension support with parts, shower and metal structures to put the controller, the assistant gear: a refined water pool, a channel pump to clean and exchange arrangements, hold pontoon, covering quality control gadgets and electrolytes. You can see a drawing of the primitive washroom gadget as should be obvious in Figure 2.1. [8]

Figure 2.3: Primitive experimental setup

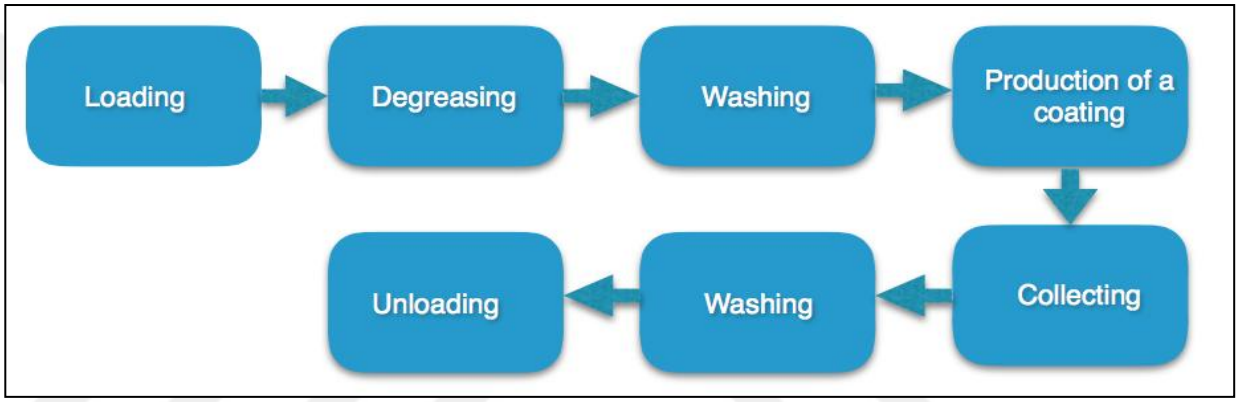


Kaynak: http://www.tte-tomsk.ru/pages_en/mdo.php (September, 2015)

2.3 TECHNOLOGICAL PROCESS OF MAO

The number of the technological operations needed in MAO is significantly smaller than that in the conventional anodic oxidation processes, which is accounted for by the absence of the numerous preliminary operations and the use of ecologically friendly solutions. After mounted on the suspension support member, degreasing is effected by treatment. [8]

Table 2.1: Technological Process Of MAO



The attendants are a technologist (higher technical education) and workers (specialized secondary education). As a rule, two workers for one shift are enough for an area of 150-200 m^2. The process in a continuous manner during the process must be controlled. [8]

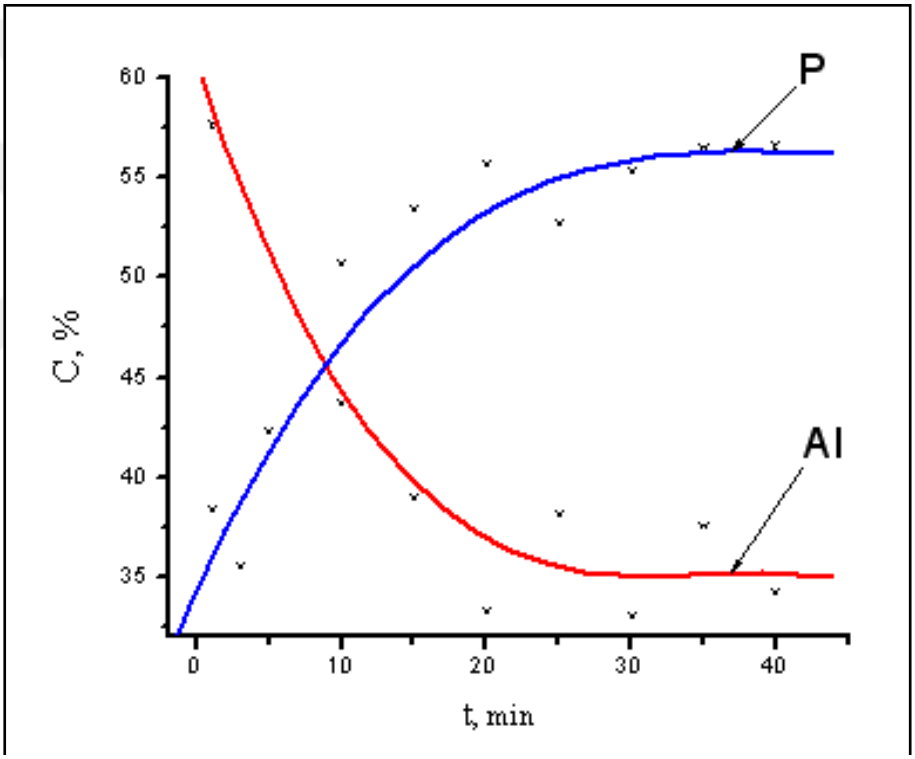
2.4 CHARACTERISTICS OF MAO'S BEHAVIOR

MAO coatings are earthenware production of a mind boggling sythesis. A covering under smaller scale bend oxidation is delivered because of oxidation of a metal surface, with the subsequent oxide and hydroxide types of the metal. In any case, then, the covering develops to the detriment of consideration of electrolyte components into its sythesis. Electrolyte components salts, oxides and hydroxides into the covering as an intricate compound. In the event that required, the oxidation innovation permits bringing any compound component into the covering. The length of time of the treatment part in the liquid builds, more components from the electrolyte is stored at first glance layer.

The reason is the expansion in the trading of electrons with expanding time because of the increment of the covering thickness.

Mixes of the base metal oxide is framed toward the end of the lower covering layer. You can likewise see variety of aluminum and phosphorus content on the surface of the MAO covering versus the treatment time in the phosphate. [8]

Figure 2.4: Variation of aluminium and phosphorus

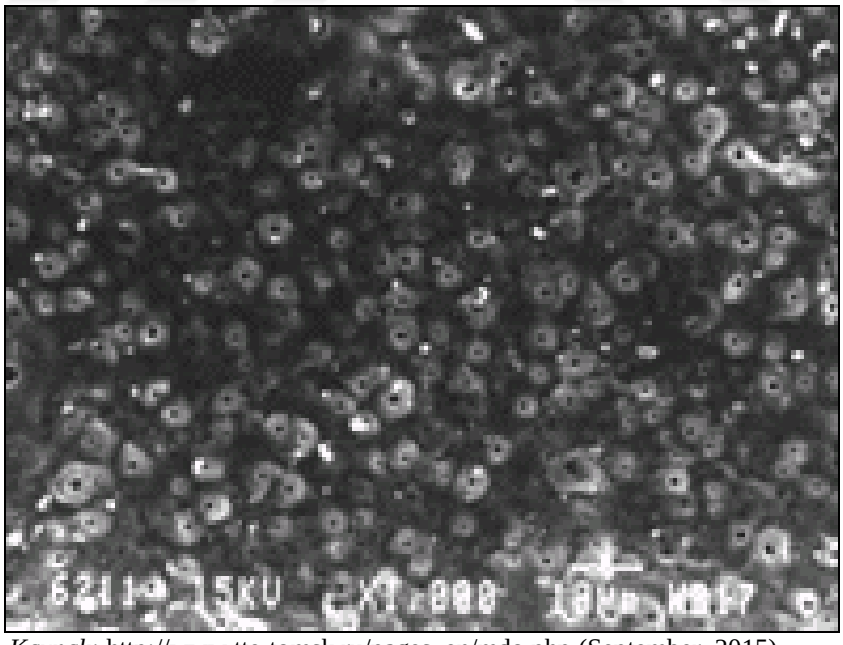


Kaynak: http://www.tte-tomsk.ru/pages_en/mdo.php (September, 2015)

The covering thickness is controlled by a few main considerations. These are the characteristic electrolytic surface treatment plan and preparing time. One percent of the MAO portions micrometers permits creation in a covering thickness in the extent. The sought covering thickness relies on upon the reason and operation conditions. For instance, a thickness of 10-15 μm is adequate for a sublayer proposed for shading, while a thickness of 100-150 μm is important to guarantee dielectric properties or high solidness. Embellishing and consumption properties under air conditions are accomplished with a

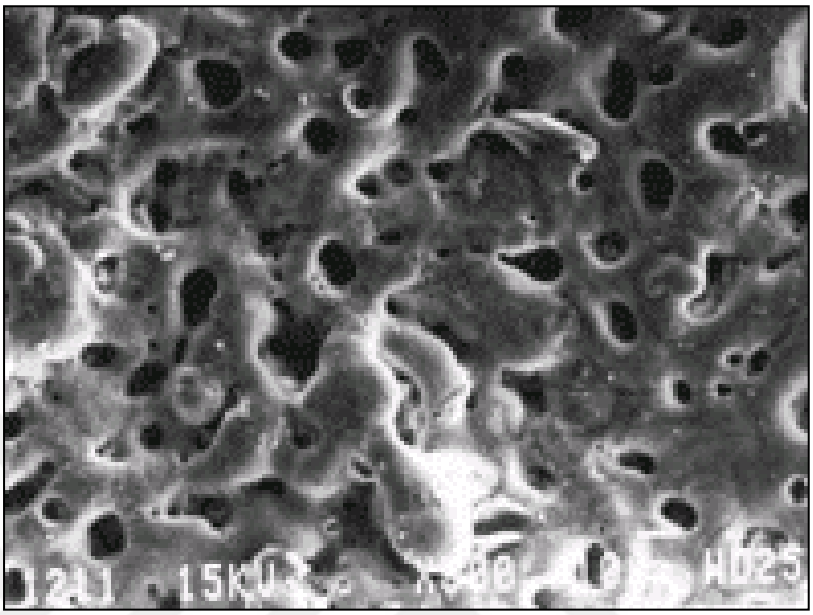
40-80-μm thickness of a cover. Porosity of the coating is between five and fifty percent. The pore structure at a covering thickness more than 10-15 microns is muddled, stretched with various arms and shut spaces. Coatings which don't contain pores are gotten in the degree of the procedure is innately difficult to acquire. In the event that required, the porosity of various materials, or a polymer (paint) might be decreased by impregnating the execution of the layer. By and large the most widely recognized utilized method is impregnation with fluoroplastics or use of polymer powder colors. [8]In various cases, porosity is a positive element. At the point when a covering experiences a wear under grease conditions, the ointment enters the covering pores and guarantees its steady passageway into the contact region. In medication bioactive MAO coatings can contain therapeutic arrangements in their pores. While framing a lump at first glance structure with the advancement of oxidation expands bubble structure. Figure 2.5, Figure 2.6 and Figure 2.7, as seen in amplified visual guess surfaces. [8]

Figure 2.5: Photomicrographs of the surface of MAO coatings x500



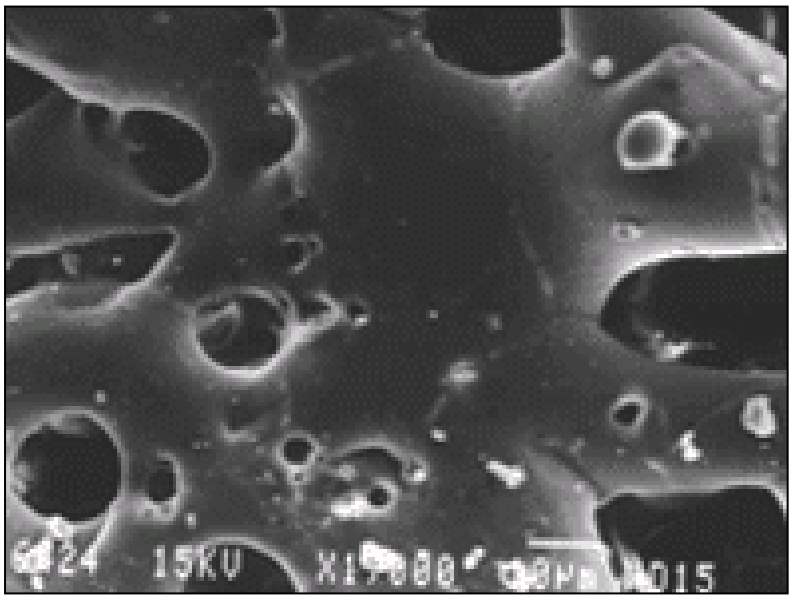
Kaynak: http://www.tte-tomsk.ru/pages_en/mdo.php (September, 2015)

Figure 2.6 Photomicrograps of the surface of MAO coatings x1000



Kaynak: http://www.tte-tomsk.ru/pages_en/mdo.php (September, 2015)

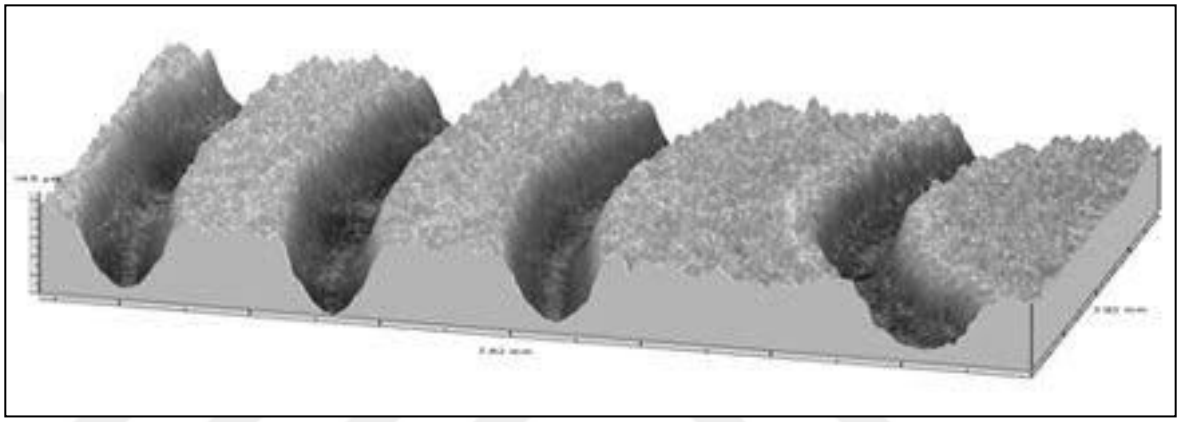
Figure 2.7 Photomicrograps of the surface of MAO coatings x17000



Kaynak: http://www.tte-tomsk.ru/pages_en/mdo.php (September, 2015)

The coatings are used as resistant to wear in various units, assemblies and mechanisms. Because this in many cases, it is possible to apply products made of aluminium, a metal, which is rather soft and complicated for the conventional methods of surface treatment. The MAO coatings exhibited less wear, particularly at raised temperatures. [8]

Figure 2.8: Wear resistance using the ball-disc method

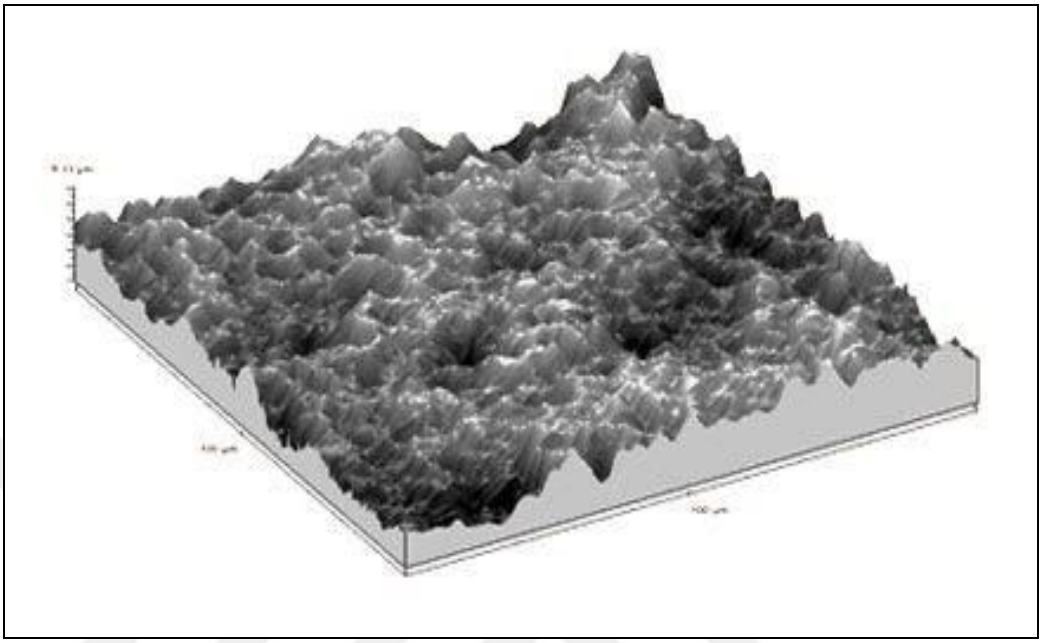


Kaynak: http://www.tte-tomsk.ru/pages_en/mdo.php (September, 2015)

MAO coatings have higher imperviousness to warm and thermocyclic loadings. The coatings can work without confinements under temperatures from - 40 to +60°C.

Amid treatment the surface harshness increments with time. One can get surfaces with an unpleasantness up to class 8. Unpleasantness relies on upon the compound material, the condition of its surface and the treatment administration. [8]

Figure 2.9: 3D profilometry of the MAO coating



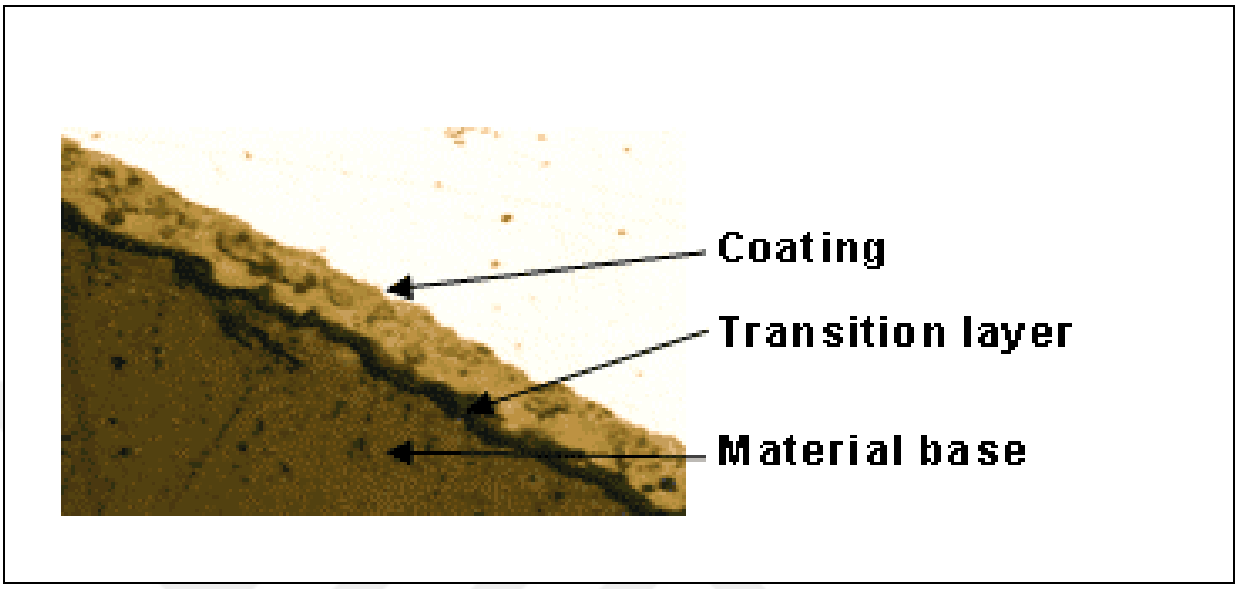
Kaynak: http://www.tte-tomsk.ru/pages_en/mdo.php (September, 2015)

The MAO method allows producing coatings which are resistant both in the atmospheric conditions and various corrosion media: chemically aggressive solutions, vapours, sea water, etc. As MAO complex compound is a ceramic coating, corrosion resistance of the coating material it is relatively high. The amount of metal base and structure control of a suitable thickness and is protected against corrosion through the pores. Additional protection can be provided by impregnating the pores with a material(most often with fluoroplastics). [8]

Both the separate voltage and consumption resistance rely on upon the covering thickness and in addition the sort and size of pores. On the off chance that the pores are loaded with a material measure of voltage can be expanded, on the grounds that the surface would build the voltage.

MAO coating are provided with a transition layer present at the interface of the metal surface, they have excellent adhesion to the metal base. The move layer is framed both inside and outside the metal. It additionally has a profile with various bendings.

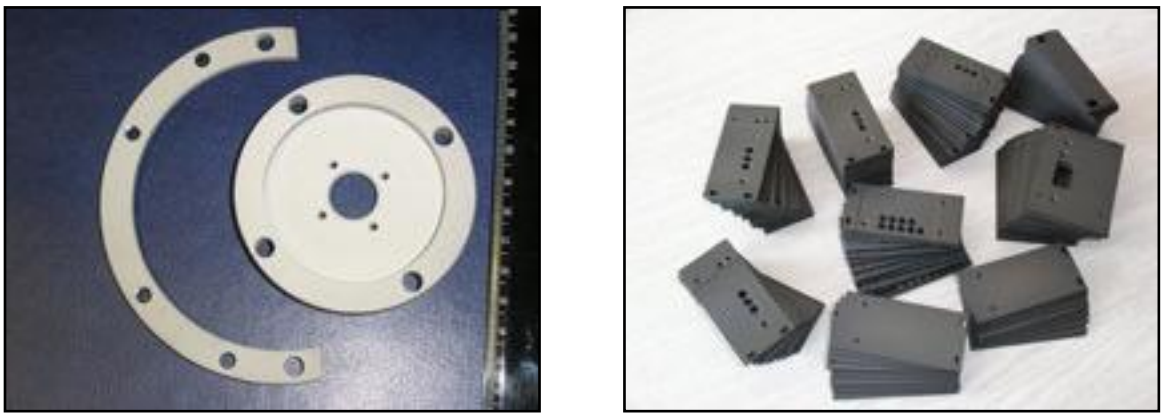
Figure 2.10: Microphotograph of the MAO coating section



Kaynak: http://www.tte-tomsk.ru/pages_en/mdo.php (September, 2015)

In consequence of, the adhesion of the coating with the metal turns out greater than the strength of the coating, so under loading the coating does not break off at the metal-coating interface. The bond values ascertained by Scratch-testing results are as high as 350 MPa.

Figure 2.11: Photo of black and white coatings

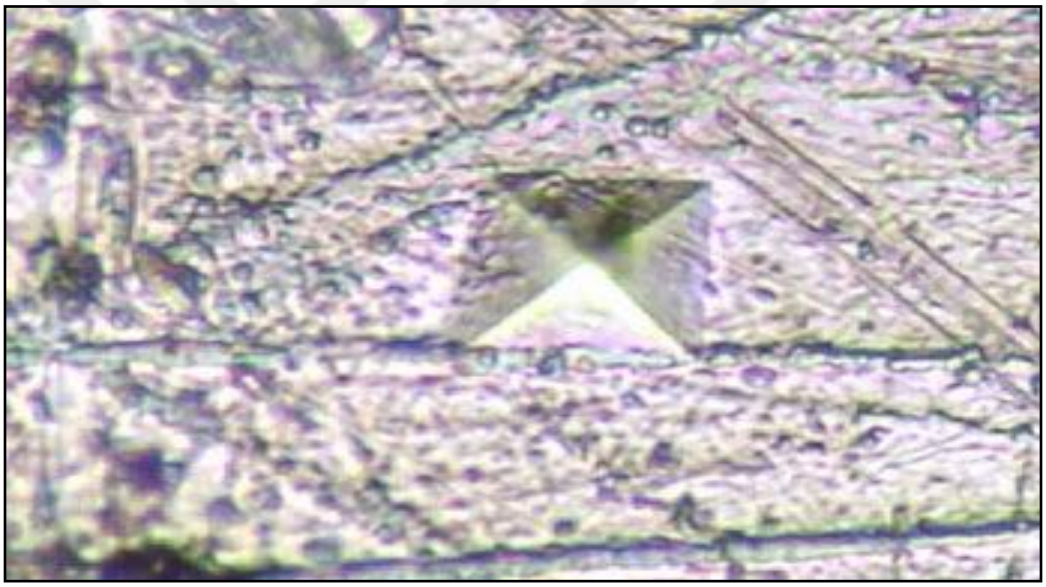


Kaynak: http://www.tte-tomsk.ru/pages_en/mdo.php (September, 2015)

The light-reflecting capacity of MAO coatings is as high as eighty percent. For dark MAO coatings the retention coefficient might be ninety percent. In request to acquire the most astounding optical qualities, amalgams are utilized with a base substance of polluting influences. [8]

The measurements were performed using a nano hardness tester, with a loading on the indentor being equal to 200 mN. The covering hardness is ascertained in view of the infiltration profundity of the indentor.

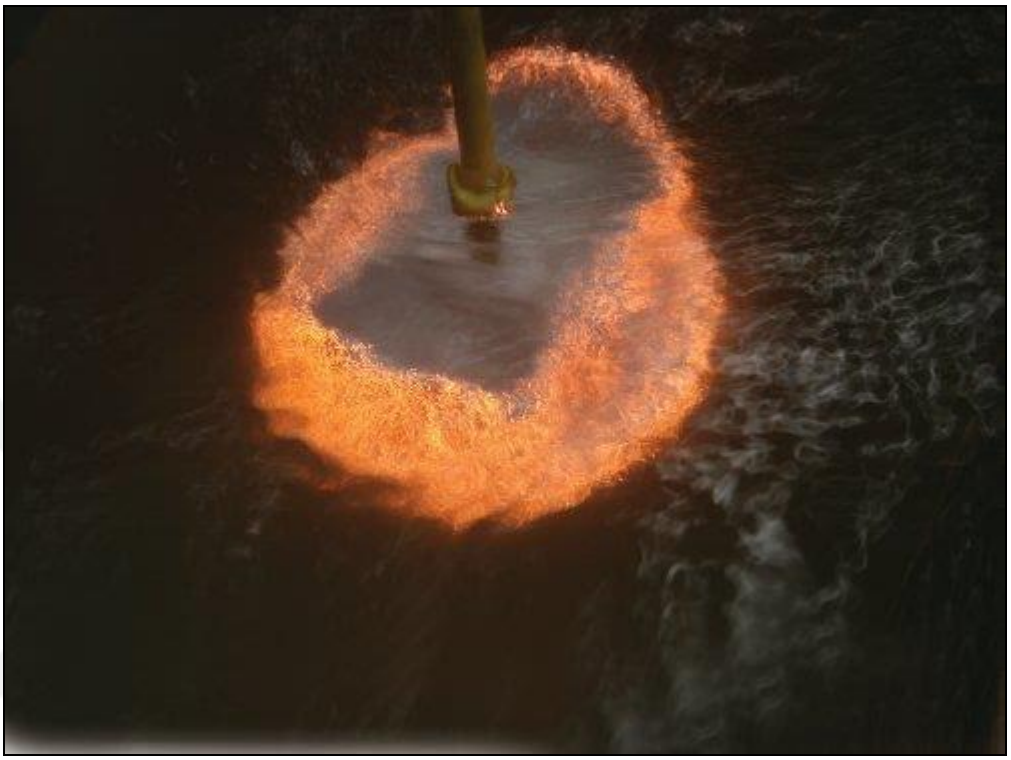
Figure 2.12: Indentor imprint obtained during microhardness investigation



Kaynak: http://www.tte-tomsk.ru/pages_en/mdo.php (September, 2015)

MAO is a multifactor-controlled process. The quality of MAO coating can be controlled by compositions of electrolyte and alloy, temperature of electrolyte, treatment time and voltage, anodic current density, and the ratio of cathode to anodic current density, etc. High quality coatings can be formed by suitable selection of deposition parameters. [8]

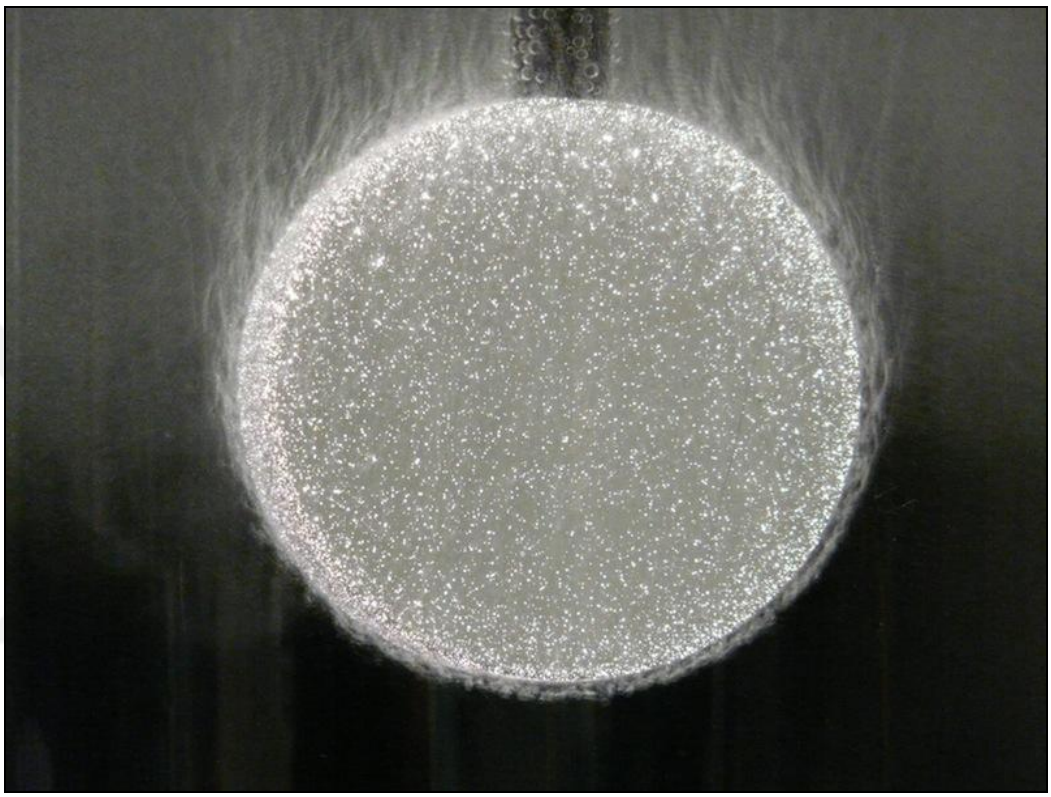
Figure 2.13: MAO Coating - Bathing process 10



Kaynak: Bora ULUĞ – Sıfıraltı / kreojenik ısıl işlemin 100cr6 ve 8620 kalite çeliklerin özellikleri üzerine etkisi

Small scale bend oxidation (MAO), otherwise called plasma electrolytic oxidation (PEO), can in-situ structure the clay coatings on the surface of valve metal, for example, Al, Mg, Ti, and their compounds. Earthenware covering created by MAO are much compacter and harder contrasted and regular surface alteration procedure, which can drastically enhance the wear resistance, erosion resistance, heat stun resistance, protection and different properties of the surface of aluminum composite. The essential segments impacting MAO technique are essentialness parameters (current thickness, voltage, beat repeat and commitment cycle), electrolyte, substrate material and working temperature, et cetera. Electrolyte portions are fundamental parameters of MAO method. Acidic and antacid electrolyte frameworks are predominantly embraced at present.

Figure 2.14: Photo of oxidation

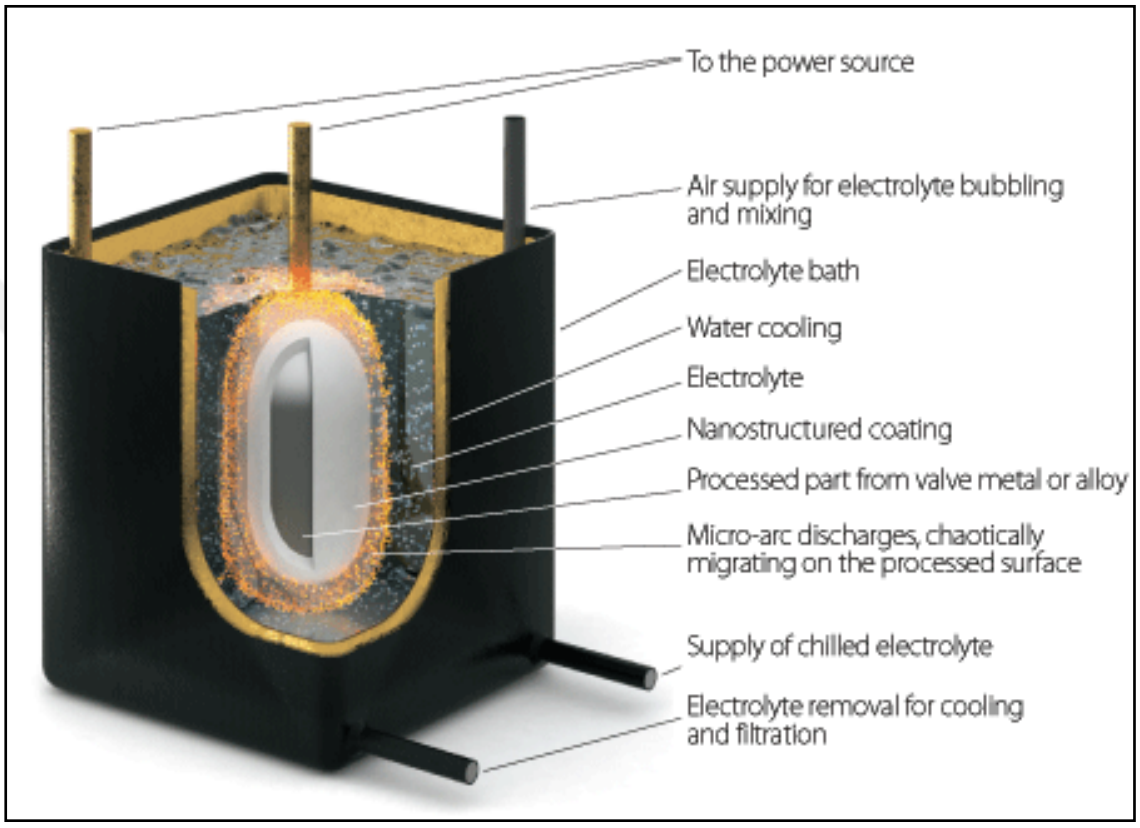


Kaynak: http://www.ibccoatings.com/plasma-electrolytic-oxidation-peo-ceratough (September, 2015)

Acidic electrolyte structures transcendently fuse sulfuric destructive, phosphoric destructive and its salt plan, at present, they are from time to time used on account of common pollution. Dissolvable electrolyte structures have no pollution on environment. Anodic reaction to change easily organize course of action and stage structure of the metal particles in the let go covering are then change to viably oppositely charged colloidal particles, and electrolytes other metal re-utilized particles are antagonistically charged may be gone into the colloidal particles and pottery coatings, in light of current circumstances, impact the properties of the aesthetic covering.

General Diagram:

Figure 2.15: The principle of micro arc oxidation method



Kaynak: http://en.rusnano.com/portfolio/companies/manel (September, 2015)

We can see on the figure 2.15 in a sectional view the details of the coating process. Here, the coating consisting of current through power bars around the sample immersed in the electrolyte liquid sample that we can see what stages.

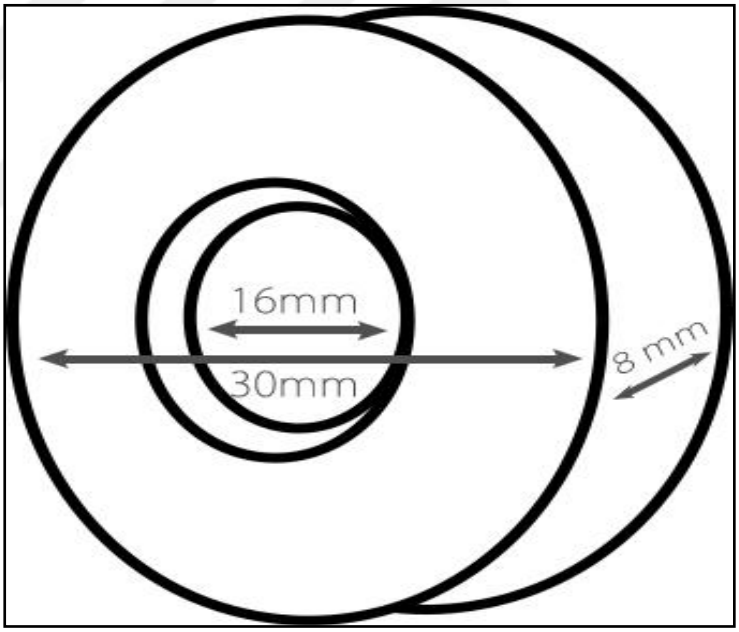
3. EXPERIMENTAL EQUIPMENT

3.1 PROPERTIES OF SPECIMENS

Specimen our thinking should be resistant to micro-arc oxidation process while ensuring we preferred the alloy AA6063. Samples were selected because of the way people living in selecting wear full equipment.

An inner diameter of 16 mm, an outer diameter of 30 mm was cut from the sample to 10 ring 8 mm. The surface was drilled to the width of the sample into the bath is important for the corrosion measurements.

Figure 3.1: The sketch of aluminium specimens (AA6063)



The chemical composition of the AA6063 aluminium alloy used as specimens is given in the Table 3.1.

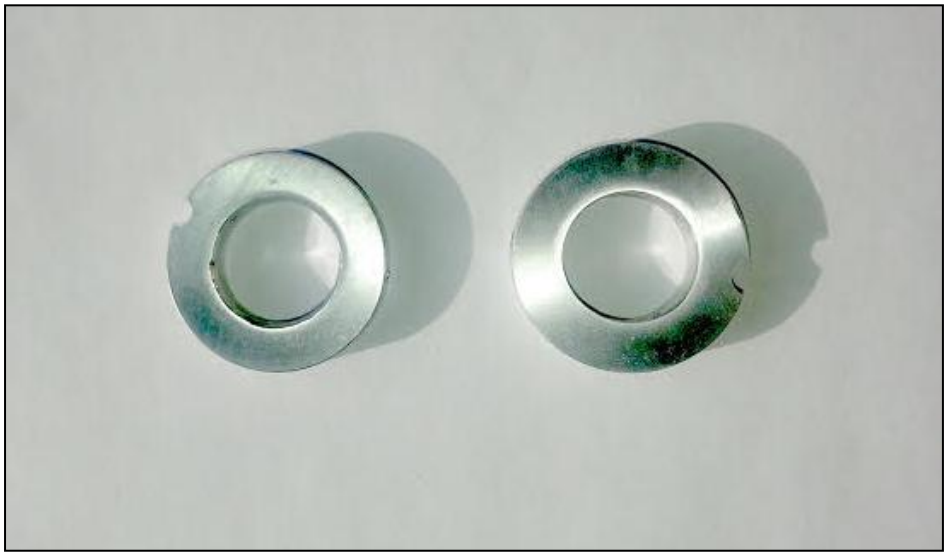
Table 3.1 The chemical composition of the AA6063 aluminum alloy

Cu (%)	Si (%)	Mg (%)	Mn (%)	Fe (%)	Cr (%)	Mn(%)	Ti(%)
0.10 max	0.20-0.60	0.45-0.90	0.10 max	0.35 max	0.10 max	0.10 max	0.10 max

Figure 3.2: The shape of aluminium specimens (AA6063)

To increase the surface tension of the Specimen during the test, we had to divide our people. Increased surface tension in order to keep within the current plan to change our plans as we perform our work with our half-ring overlay measurement samples.

Figure 3.3: Close-up photo of samples (AA6063)



3.2 TEST EQUIPMENT

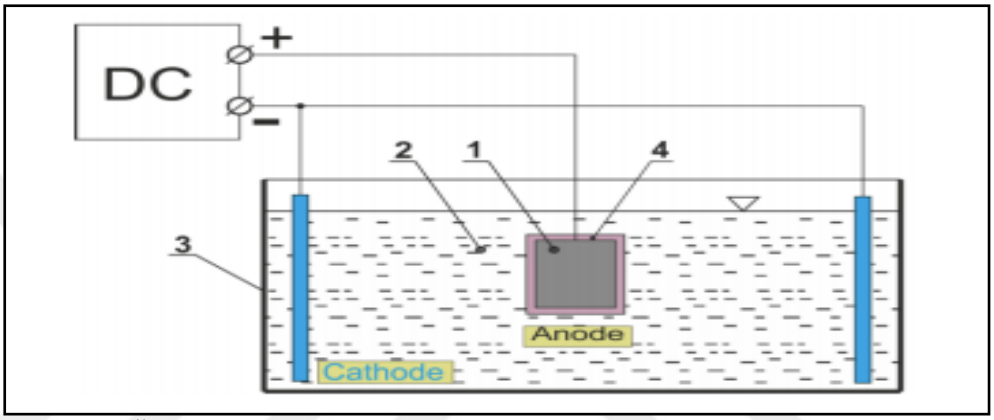
Figure 3.4: Micro Arc Oxidation power machine

As it is seen in the Figure 3.4 bathroom connected to the power unit consisting of micro-arc oxidation unit.

Bathing Solution of MAO process:

The electrolytic solution consists of distilled water with NaSPO3 and Na3PO4. The tank is filled with 200 litres of distilled water with 10 grams of NaSPO3 and 3 grams of Na3PO4 per litre.

Figure 3.5: Bathing Solution of MAO process



Kaynak: D. Vaňa, 1Š. Podhorský, 2 M. Hurajt, 3 V. Hanzen4 - Surface Properties of the Stainless Steel X10 CrNi 18/10after Aplication of Plasma Polishing in Electrolyte

Figure 3.6: Abrasion Device

4. RESULTS AND DISCUSSION

Our first sample was prepared from an aluminum alloy that we begin to try to increase the surface tension when the samples were immersed in the bath. Samples of the second party to advance in the way we have planned cut in half before dipping bath. In this way, we made a few pieces of the first sample we divided into two trials. According to the sample stream, combined with 400V and 460V, giving the bath fluid and flow we achieve our coating.

Figure 4.1: Coating - 400V

Figure 4.2: Coating - 460V

Figure 4.3: The greater part of the examples

Figure 4.4: Close up photo, Coating - 400V

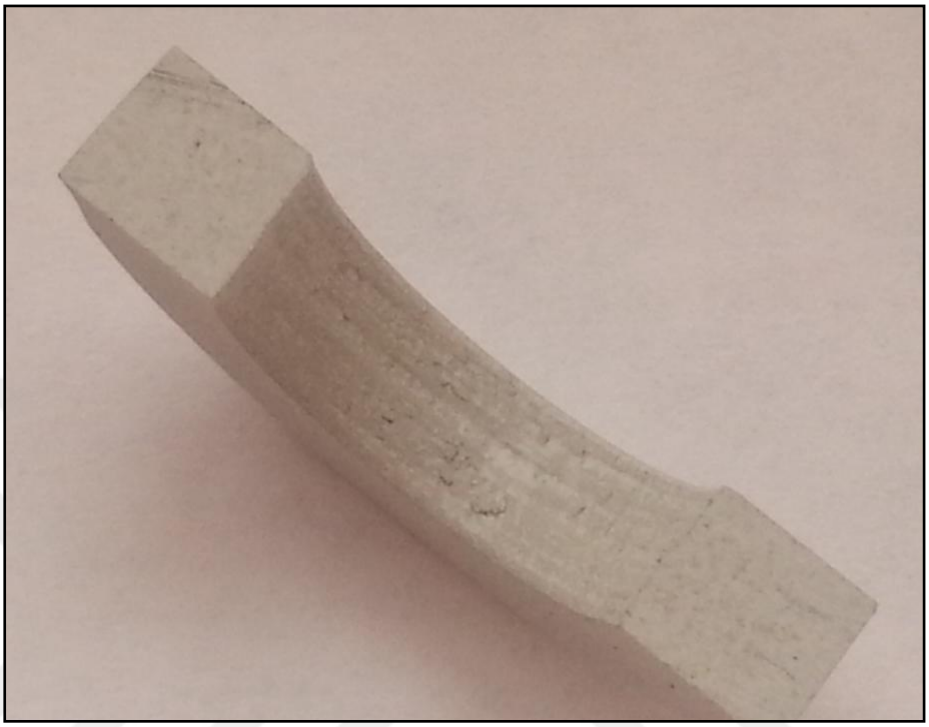


Figure 4.5: Close up photo, Coating - 460V

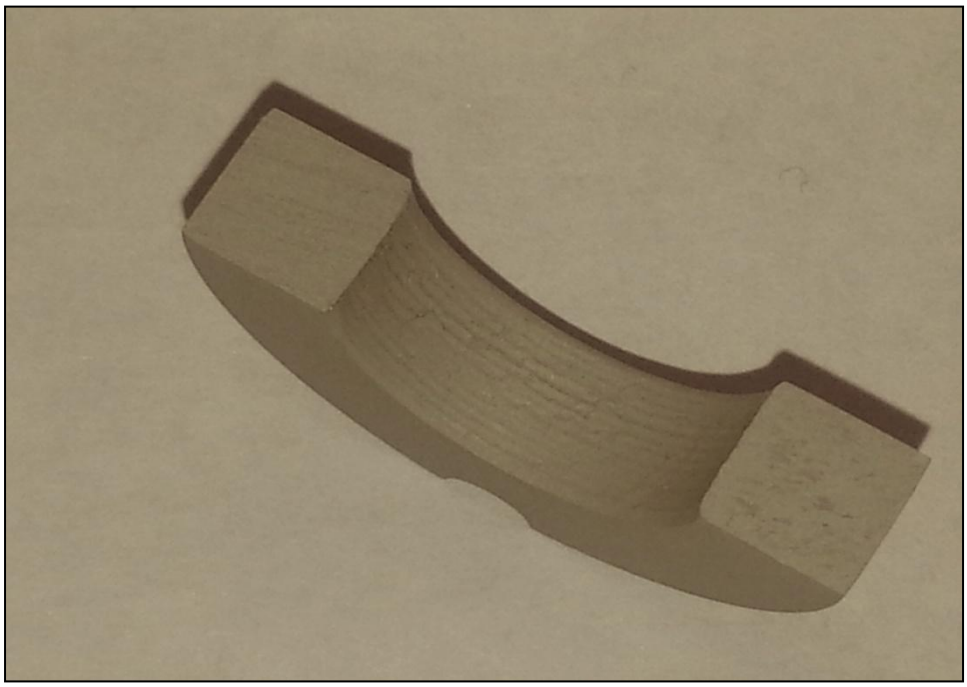
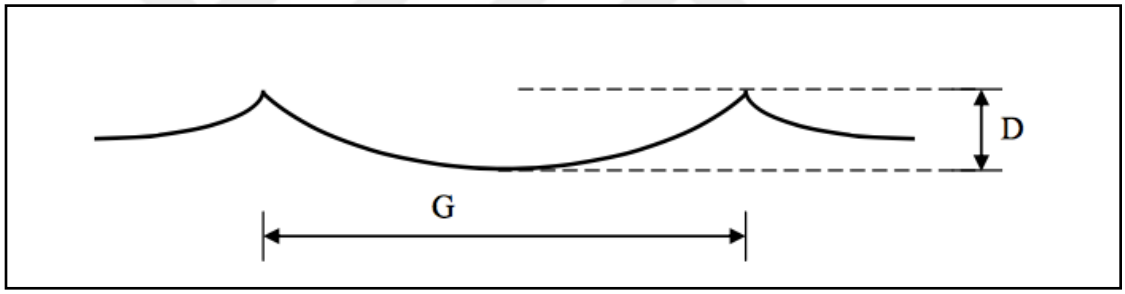


Figure 4.4 and Figure 4.5 ta seems to be a way of coating layer, as shown in the close-up of samples. Aluminum held here has kept a thicker structure than 400V 460V current. At approximately two samples has a coating thickness between 0.5 mm differences like. Here is a riveted together despite a strong structure of micro-arc oxidation process to make a layered coating.

Coating as a result of abrasion effect made on the samples within the Friabilitor 400V coated samples and the relative values of abrasion resistance on coated samples was calculated 460V.

Figure 4.6: The inverse of the wear scar area, expressed as wear resistance



Kaynak: Bora ULUĞ - Sıfıraltı / Kreojenik ısıl işlemin 100Cr6 ve 8620 Kalite Çeliklerin ÖzellikleriÜzerine Etkisi

Because each sample is equal to the amplitude of the reciprocal movement for wear tests, wear track area, calculated from the track profile, the amount of vaccine material was taken as a measure. The inverse of the wear scar area, expressed as wear resistance. Abrasion resistance in the hardened condition of each steel and the wear resistance of other samples taken as 1, the relative corrosion resistance quality of the sample divided by the abrasion resistance in the hardened condition of 6063 was obtained. [13]

$$A = \frac{(\pi GD)}{4}$$

***Wear Trail Area

A= Wear Trail Area

G= Track width

D= Trace depth

It is clear from the above formula, then we calculate the measured abrasion trace depth and track width. According to this measure, we calculate the relative wear resistance. You will find that we have calculated the values of wear Table 4.1.

Table 4.1: Relative Corrosion Values

Non-Coated	400 V	460 V	Value
142334	50565	511	**A**
1	2,81	278,5	**Relative corrosion**

We see on value in Table 4.1 are the traces of wear on the trail area calculated by multiplying the sample depth and width. Optical glasses apparatus projected depth we place our samples on the projection device and allows us to calculate the width. In this area we give the formula used when calculating the Figure 4.7.

The coating of the values contained here in AA6063 aluminum alloy relative wear resistance we assume 1. The results of our calculations showed that up here coating thickness is directly proportional to the resistance, abrasion resistance of the coating with increasing gain.

Figure 4.7: Graph based on resistance of the coating thickness

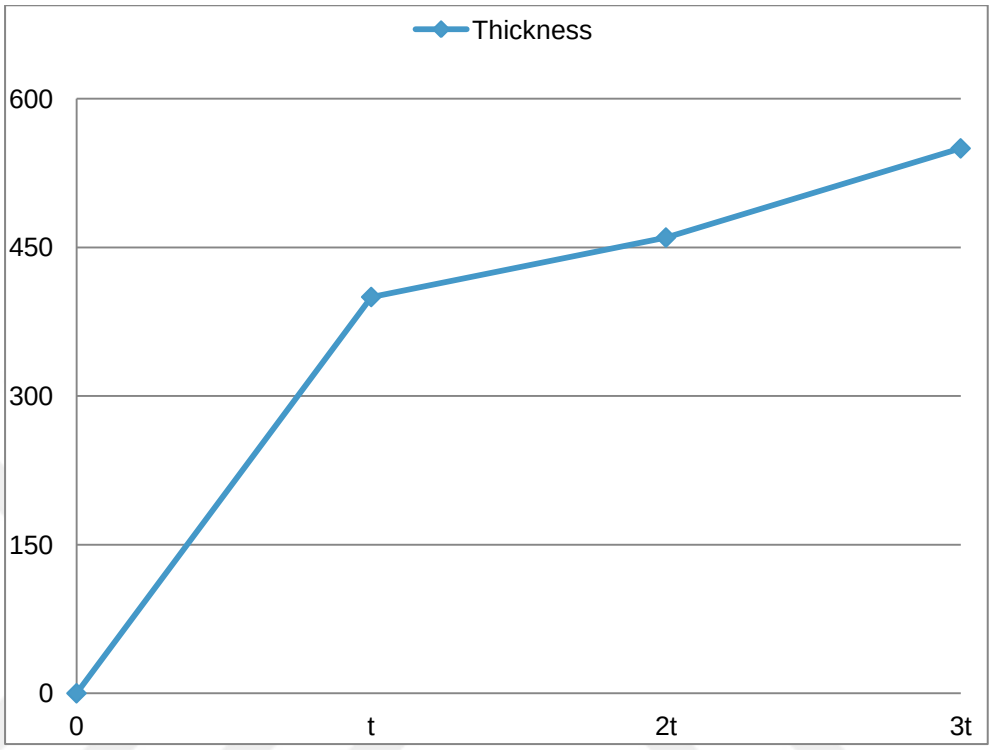
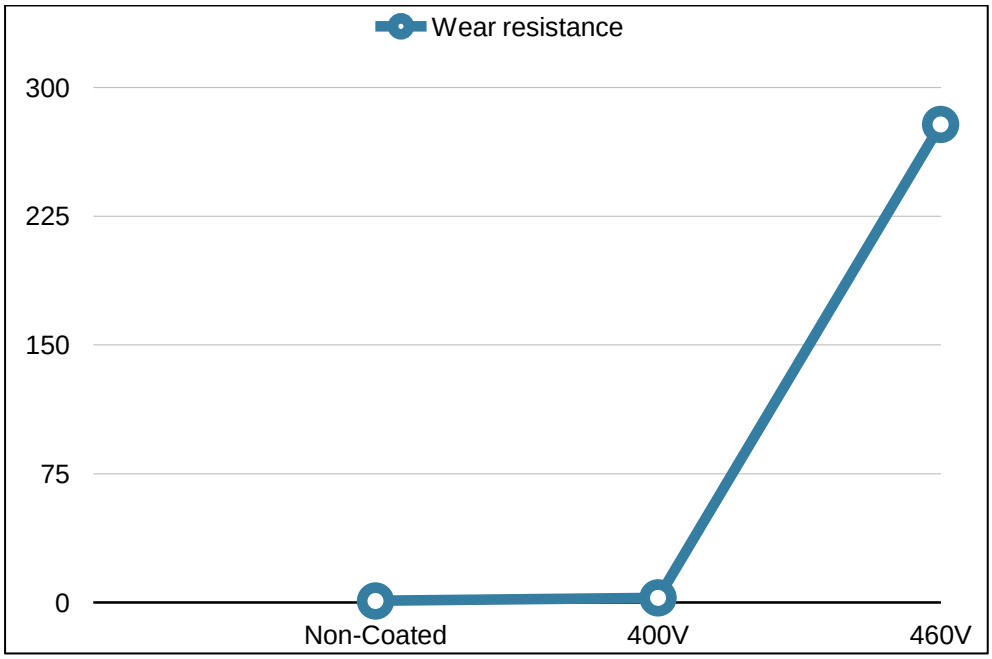


Figure 4.8 : Time-dependent change of the coating thickness



5. CONCLUSION

According to the Micro Arc Oxidation Coating (MAO), experimental results, the effect of the coating thickness on MAO coating process can be summarized as follows; ;

a) Micro Arc Oxidation is a method for making strong coatings are riveted together,

b) Low-cost materials such as aluminum alloy micro arc oxidation method has made it stronger coatings by saving both time and cheaply,

c) We can approach the strength of the ceramic material in our thesis and we are looking for a standard that we can come cheap, micro-arc oxidation process has been the call and answer our method,

d) A 6063 alloy corrosion resistance of a soft material, though we could have done a coating approximately 280-fold increase,

e) Here's how we have progressed more different materials may also exhibit the same characteristics,

f) Improving the corrosion resistance of the coating thickness is proportional manner, we have identified,

g) You need to increase the sample holding times to increase the coating thickness that we have experienced, but it should also ensure that the current conditions for doing so to the melting of the sample.

From these results it is explained that the hydraulic valves behavior does not change the coating material cost but definitely changes the resistance durability so this treatment has a positive effect.

As a result, micro-arc oxidation method has proven itself in our direction, our experiment with many advantages. Its abrasion resistance, thermal resistance, which makes this method more important in the high hardness aerospace and automotive industries.

If you come up with the solution process goes to research on this method would be the best method for coating light metals.

This study is a new application, this may be the first method used for this purpose. Considering the value to be used in this study, it is evaluated that the MAO hydraulic valves may be practical by this work. Mass production will provide a great convenience. 50 million valves are used in a year at the region of Turkey. This way we will reduce the imported products cheaper in overseas work to guarantee the quality of the material and will switch to the domestic production. Technology that used in this work may become a new useful method. Micro arc oxidation method helped to develop optimum thickness of the success of this research.

ACKNOWLEDGEMENTS

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Aluminum samples were provided by Yıldız Technical University. Preliminary training in the operation of each device wear Istanbul University was also taken. Many thanks and appreciation for these establishments.

REFERENCES

[1] http://www.hidropaks.com.tr/uploaded/files/hidrolik%20valf.pdf - Hidrolik Valf Çeşitleri ve Çalışma Yöntemleri (September, 2015)

[2] http://hidroliksistemler.blogspot.com.tr/2010/06/hidrolik-valfler.html (September, 2015)

[3] Cenk MISIRLI, Mümin ŞAHİN and Ufuk SÖZER - Effect of Micro Arc Oxidation Coatings on the Properties of Aluminium Alloys

[4] Prof.Dr.Ayşegül AKDOĞAN EKER - Seramik Malzemeler (September, 2015)

[5] Gökhan BAŞMAN, Erdem ATAR, E. Sabri KAYALI, Seramik malzemelerin aşınma davranışı

[6] http://www.metaluzmani.com/?page_id=312 (September, 2015)

[7] Zhaohua JIANG, Xuetong SUN, Yanping LI, Fuping WANG and Yandong LÜ - Effect Of The Oxidation Time on Properties of Ceramic Coatings Produced on Tİ-6Al-4V by Micro Arc Oxidation

[8] http://www.tte-tomsk.ru/pages_en/mdo.php (September, 2015)

[9] https://en.wikipedia.org/wiki/Plasma_electrolytic_oxidation (September, 2015)

[10] http://www.pfonline.com/articles/peo-coatings-sparking-new-interest (September, 2015)

[11] http://www.ibccoatings.com/plasma-electrolytic-oxidation-peo-ceratough (September, 2015)

[12] http://en.rusnano.com/portfolio/companies/manel (September, 2015)

[13] Bora ULUĞ - SIFIRALTI / KREOJENİK ISIL İŞLEMİN 100Cr6 ve 8620 KALİTE ÇELİKLERİN ÖZELLİKLERİ ÜZERİNE ETKİSİ

[14] D. Vaňa, 1Š. Podhorský, 2 M. Hurajt, 3 V. Hanzen4 - Surface Properties of the Stainless Steel X10 CrNi 18/10after Aplication of Plasma Polishing in Electrolyte

[15] Y.J.Liu, J.Y.Xu, W.Lin, C.Gao, J.C.Zhang and X.H.Chen - Effects of Different Electrolyte Systems on the formation of Micro- Arc Oxidation Ceramic Coatings Of 6061 Alumını