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Effects of Micro Arc Oxidation on Metal Materials and Application Potential

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Abstract. Micro arc oxidation (MAO) is a surface treatment technique that involves forming a ceramic layer by processing metal surfaces under high voltage in an electrolytic environment. This method is widely used to strengthen and protect the surfaces of light metals, especially aluminum and its alloys. The effects of MAO on metal materials include changes in the mechanical, chemical and optical properties of the formed ceramic layer. Additionally, industrial applications and future potential of MAO are also discussed. The micro arc oxidation process creates a very thin and hard ceramic layer on metal surfaces. This ceramic layer increases the material's resistance to corrosion, wear and high temperatures. Additionally, the ceramic layer allows the surface to become smooth and coatable. As a result of the MAO process, the microstructure and composition on the material surface can change, allowing customized surface properties to be obtained according to different application requirements. Micro arc oxidation has broad application potential in many industrial sectors. It is widely used to strengthen and protect the surfaces of metal parts used in areas such as automotive, aerospace, defense, energy and medical devices. For example, in the automotive industry, the MAO process is used to strengthen the surfaces of vehicle body parts, engine components and other parts. In the aviation industry, MAO process is applied to increase the resistance of aircraft engine parts to high temperature and wear conditions. Micro arc oxidation process is an important surface treatment technique for strengthening and protecting the surfaces of metal materials. This method, which has a wide application potential, is widely used in industrial applications to meet surface protection and reinforcement requirements. In the future, it is expected that MAO technology will be further developed and its application areas will be expanded.

INTRODUCTION

The history of the micro arc oxidation (MAO) process is quite interesting and has been developed by various researchers at different times. The first studies on the MAO process were conducted in the Soviet Union in the 1950s and 1960s while research was being conducted for military applications. During this period, the search for new methods to protect and strengthen metal surfaces allowed the development of the MAO technique, which involves forming a ceramic layer by processing metal surfaces under high voltage in an electrolytic environment. Micro arc oxidation, which became known all over the world, especially in Japan in the 1970s in the United States and in the late 1980s, is still a current and widely studied research topic today.[1]

Japanese scientists have explored the potential of MAO, especially on aluminum and its alloys. During this period, the first studies on industrial applications of MAO were also carried out. Since the 1990s, the MAO process has become more widely used and its industrial applications have expanded. MAO process is preferred to strengthen and protect the surfaces of metal materials, especially in the automotive, aerospace, defense and energy sectors. During this period, research and technical developments on the MAO process continue. Today, the micro-arc oxidation process is recognized as an important surface treatment technique for strengthening and protecting the surfaces of metal materials. Researchers and industry experts continue to work to further expand the potential of this method.[2] Many terms are used to describe the micro arc oxidation process: These include spark anodic

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oxidation (spark anodizing), anodic spark deposition, micro arc anodizing, micro plasma anodic oxidation (microplasma anodizing). micro plasma oxidation, plasma electrolytic oxidation and electroplasm oxidation.[3-4]

Equipment and Processes of Micro Arc Oxidation

Microarc oxidation is carried out by applying a high voltage electric current on an electrolyte solution on the surface of metal parts. During the process, a small micro-scale arc gap is created on the metal surface, causing local heating of the surface and initiation of oxidation. Hardware elements basically consist of a power supply, an electrolyte bath, anode, cathode and cooling system. Micro arc oxidation process can be defined as creating an arc on the anode by applying negative voltage to the anode sample immersed in electrolyte and positive voltage to the cathode and oxide coating the sample surface.[5]

In this process, stainless steel containers, usually cooled with water and containing the electrolyte, are used as cathodes. The sample to be subjected to micro arc oxidation is used as the anode. One of the direct current, pulsed direct current, unbalanced alternating current or heteropolar pulsed current power sources is used as the power source.[1]

By applying negative voltage to the sample, which is the anode, oxide film formation begins on the material surface. This stage is the classical anodic oxidation process. However, when the applied voltage exceeds a certain critical value, the micro-arc oxidation process begins with arc formation on the material surface. The voltage value at which these micro-sized arcs occur on the material surface is defined as the dielectric breakdown. At the decay voltage value, metal ions and hydroxyl ions move in opposite directions on the material surface and initiate oxide formation.[6] The critical potential difference required for arc formation depends on the electrode material and electrolyte composition and is not affected by temperature, electrolyte concentration and surface tension. Theoretical studies show that the local temperature on the material surface can reach several thousand Kelvin.

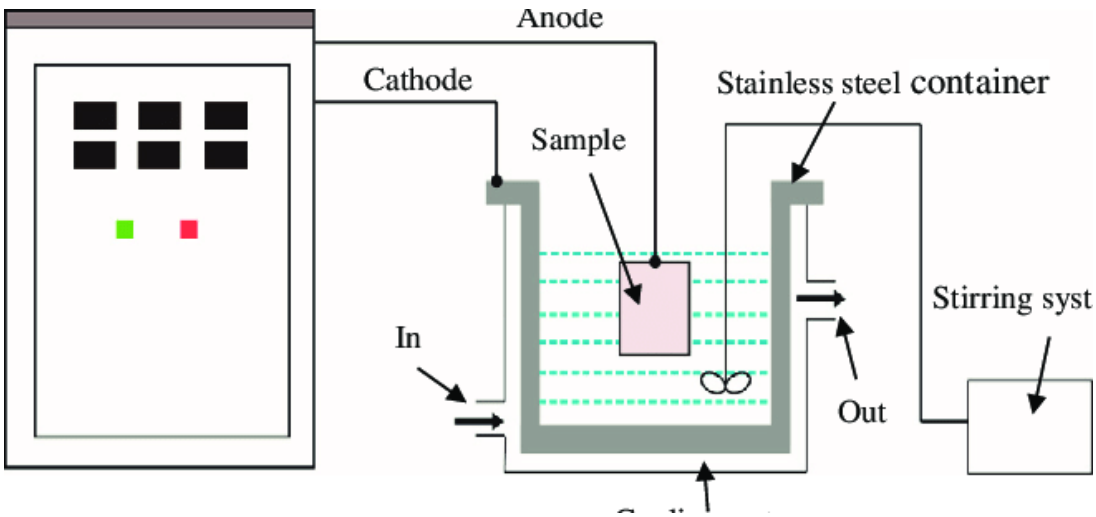

FIGURE 1. Micro arc oxidation apparatus

Application Areas of Micro Arc Oxidation

The micro arc oxidation process can easily compete with anodizing and thermal oxidation methods in many industries, with its low weight and low cost alternative to currently used materials that are difficult to produce or process. Thanks to the excellent wear, corrosion resistance, friction and thermal properties of the coatings produced by the micro arc oxidation method, the micro arc oxidation process is widely used in the aerospace industry, gas/oil industry, textile machinery, biomedical industry, vacuum engineering, shipbuilding industry, cutting and It has applications in fields such as pressing tools, mechanical industry, electrical engineering and electronics.[1]

Some of the important application areas of micro arc oxidation:

1. Automotive Industry: Micro arc oxidation is widely used in the automotive industry. It is especially applied in components that require high wear and corrosion resistance, such as suspension parts, engine parts, wheels and exhaust systems. In this way, the life of automobile parts can be extended and their durability increased.[7]

2. Aviation Industry: In the aviation industry, micro arc oxidation is widely used to increase the durability of airframe and engine components of aircraft. This process strengthens the surfaces of parts operating under high temperature and pressure and protects them against corrosion.[7]

3. Military Applications: Micro arc oxidation also plays an important role in military applications. This technology is frequently used to increase the durability of military vehicles and equipment, protect them from corrosion and increase their resistance to enemy effects.

4. Medical Devices: Medical devices are processed by micro arc oxidation due to sterility and durability requirements. This process strengthens the surfaces of surgical instruments, prostheses and implants and reduces the risk of bacterial contamination. In the biomedical industry, the biocompatibility of titanium alloys used as implants and endoprostheses has been increased by micro arc oxidation process.[7]

5. Electronics Industry: In the electronics industry, micro arc oxidation is used to treat the surfaces of semiconductor devices. This process improves the thermal and electrical properties of semiconductors and increases their durability.

6. Defense and Security Systems: In defense and security systems, micro arc oxidation is used to strengthen and protect the surfaces of military equipment and security equipment. This is important for the long-term use of the equipment and its resistance to harsh conditions.

Advantages and Disadvantages of Micro Arc Oxidation

In micro arc oxidation technology, sample preparation before the process is less important than other technologies. This allows the production process to run faster and the environmental impact of the solutions to be used in sample preparation before the process to be minimized. Another advantage of micro arc oxidation technology is that it can be applied to a wide range of materials such as aluminum, magnesium, titanium, niobium, zirconium, and high copper-containing aluminum alloys and high silicon-containing casting materials, which are difficult to coat with the traditional anodic oxidation method, can be coated up to 300μm thick with this method.[8-9] MAO technology is an environmentally friendly coating method that does not contain toxic waste and is an alternative to traditional coating of light metals. Thanks to the unique wear and corrosion resistance it provides, Al, Ti, Mg, etc. can be used instead of steel-based parts used especially in the automotive industry. It allows the use of light alloys.[10]

The main advantages of the MAO process are; no need for preliminary or final surface treatments, use of environmentally friendly and inexpensive electrolytes, ability to use the coating color for decorative purposes by changing it, obtaining coatings with high hardness (2000 HV for Al), creating surfaces with low coefficient of friction (f = 0.005-0, 01). It has high wear resistance, can be used as a thermal barrier coating due to its high temperature resistance and is resistant to corrosion in various environments.[11]

As with other technologies, micro arc oxidation also has some disadvantages. High voltage (over 1000 V) and power supply capacity (more than 1 MW) are required to carry out the micro arc oxidation process in large-scale products. This means high energy consumption and a hazardous production environment, as does product scale and part size. Gear making tools and materials have a lot to do with the expected high voltage usage. This technology does not cause burning as in sulfuric solid anodization. However, removing the arc formed during contact between the gear, part and masking is a serious problem.[12]

Materials That Can Be Coated by Micro Arc Oxidation

Micro arc oxidation is a process used to oxidize the surfaces of various metals. This process is generally applied to materials such as light metals such as titanium, aluminum and magnesium, and titanium alloys. Here are some materials that can be coated by micro arc oxidation:

Aluminum and Aluminum Alloys: Aluminum is one of the most common materials that can be coated by micro arc oxidation. Aluminum alloys are also suitable for this process. Micro arc oxidation protects the surface of aluminum against corrosion and increases its durability.

Titanium and Titanium Alloys: Titanium and titanium alloys are another group of materials that can be processed by micro arc oxidation. This process makes the surface of titanium more durable and increases its resistance to corrosion.

Magnesium and Magnesium Alloys: Magnesium and magnesium alloys can also be coated by micro arc oxidation. This process protects the surface of magnesium from corrosion and increases its resistance to wear.

Various Metal Alloys: Micro arc oxidation can be used to machine the surfaces of various metal alloys. For example, magnesium and aluminum alloys.

The oxides formed by the metals in this group are stable under open circuit conditions (corrosion potential) and are difficult to corrode. If the potential of the metal electrode is increased in the positive direction by applying metal current, almost all of the current passing through the circuit will be consumed for the growth of the oxide film on the surface. In addition, it is possible to coat the surfaces of metals that cannot be coated with this method, such as stainless steel, by modifying them with various processes.[13]

Conclusion

Micro arc oxidation is an effective process to strengthen and protect the surfaces of metal materials. This process increases the durability of aluminum, titanium, magnesium and many other metal materials, increases their resistance to corrosion and adds certain functional properties. The oxide layer formed by micro arc oxidation extends the life of metal parts and expands their usage areas. In this article, the effects of micro arc oxidation on metal materials are examined and its application potential is evaluated. The durability of metal parts processed by micro arc oxidation increases, their resistance to corrosion increases and their mechanical properties are improved. Additionally, this process has a wide industrial application potential, being used in automotive, aerospace, defense, medical and many other industries. However, metal materials coated by micro arc oxidation also have some disadvantages. This process often requires expertise and is complex to implement. Additionally, some undesirable consequences such as increased surface roughness may occur. However, when applied correctly, microarc oxidation is a powerful tool to improve the performance and durability of metal materials. As a result, micro-arc oxidation is an important process to improve and protect the surface properties of metal materials. It is expected that this technology will be further developed and become more common in industrial applications. Micro arc oxidation will play an important role in making metal materials more reliable and durable in the future.

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