Improved Technology for Hard Anodizing Dissolution of Aluminum Alloy Part

Lixia Peng* and Man Li

Department of Automation Engineering, Xi’an International University, Xian, Shanxi, 710077, China

Abstract: This paper deeply analyzes the main factors of the dissolved problems arising in the process of aluminum alloy hard anodizing, combined with the specific problems occurring in production practice, introduces in detail the method and thought to analyze and investigate the causes of dissolving, and puts forward targeted improvement technology. This paper is practically instructive and significant for the production practice to effectively solve the problems of the dissolved situations arising in the process of tube parts hard anodizing.

Keywords: Aluminum alloy, dissolution, hard anodizing.

1. INTRODUCTION

Aluminum alloy is the optimum lightweight material in aerospace industry. What’s more, after processing by hard anodizing, the hardness, corrosion resistance, insulativity, wear resistance and high temperature of aluminum alloy is all increased significantly, and its application is gradually wide. The application of technology of hard anodizing of aluminum alloys is wide [1], and it has been a mature surface treatment process. However, during the course of oxidation, there are kinds of inevitable problems encountered that influence the quality of oxidation film. And the phenomenon of local dissolution or complete dissolution is one of the most common phenomenon that influence surface quality disposed of parts [2, 3]. In this paper, we are going to analyze hard anodizing dissolution of aluminum alloy part and deeply discusses the problem of matrix dissolution and put forward the constructive improved technology.

2. THE MECHANISM OF HARD ANODIZING OF ALUMINUM ALLOY PART

The process of growth of anode oxide film is proceed in a conflict process of the thickening and dissolution of film [4]. The electrolyte is energized; a layer of AL2O3 film was prepared on aluminum substrate surface, chemical reaction:

\[
2OH^- - 2e \rightarrow H_2O + O^{2-} \quad (1)
\]
\[
2AL^{3+} + 3O^{2-} \rightarrow AL_2O_3 + Q \quad (2)
\]
\[
6OH^- + 2AL^{3+} \rightarrow 3H_2O + AL_2O_3 + Q \quad (3)
\]

Meanwhile, the electrolyte dissolved the aluminum substrate and the oxidation film, chemical reaction:

\[
2AL + 6H^+ \rightarrow 2AL^{3+} + 3H_2 \quad (4)
\]
\[
AL_2O_3 + 6H^+ \rightarrow 2AL^{3+} + 3H_2O \quad (5)
\]

The process of oxidation film growth such as shown in Fig. (1). At the moment of energizing, since the strong appetency of oxygen and aluminum, the surface of aluminum swiftly develop a layer of compact nonporous oxidation film, and the thickness is generally 10~150 nm based on the cell voltage. The oxidation film is high insulative, it is named barrier layer [5]. Since expanding when aluminum oxide forms, the barrier layer becomes rough and uneven in surface. First of all, the oxidation film is dissolved by electrolyte and forms hole at the thin film layer. Then electrolyte enters into the surface of aluminum matrix by hole, which makes electrochemical reaction continue, and cavity is changed into porous layer, which is dozens µm. As the electrolysis is happening, the porosity of the porous layer becomes more and more deep, and barrier layer begins to develop in the direction of aluminum matrix gradually. Finally, the porous oxidation film that compounded by barrier layer and porous layer is formed. The development process of film is a synergistic effect between electrochemical reactions and chemical reactions. When electrochemical reactions more quickly than chemical, the film is net growth and the thickness is increased, on the contrary, oxidation film will dissolve and thickness will decrease. If given enough time, the formation of oxidation film will completely dissolve in electrolyte [6-8].

![Fig. (1). Growth process of hard anodizing film.](image-url)
3. THE REASON ANALYSIS AND CONTROL MEASURES OF HARD ANODIZING DISSOLUTION OF ALUMINUM ALLOY PARTS

The thickness and hardness of hard anodizing film is closely related to electrolyte concentration, temperature of electrolyte, current density, oxidation time, alloy composition and other factors [9]. And the phenomenon occurs is mainly determined by above factors.

3.1. The Influence of Electrolyte Concentration

Generally speaking, in sulfuric acid hard anodizing craft, if the content of sulfuric acid is low, the hardness of oxidation film will be high. But in regard to aluminum alloy which is high copper content should not adopt the low concentration of electrolyte, or else, it will cause parts dissolving. Thus, electrolyte should be selected according to material. In mixed acid hard anodizing craft, it needs to add certain components of organic acids, whose purpose is to improve oxidizing temperature and reduce producing difficulty [10].

3.2. The Influence of Temperature of Electrolyte

In general, in the range of process stipulation, as the reduction of temperature, the hardness and abrasive resistance will gradually improve. In order to get the high quality of oxidation film, the temperature fluctuations of solution that in the oxidation process should be small as possible, it's best to control the temperature among the range of ±2°C. Since excess of electricity will cause localized heat cannot be lost, it will cause oxidation film partly or completely dissolve. In order to control the temperature of electrolyte, aluminum anodizing often need equip with bend cooling pipe or other cooling equipment in the wall of electrolyzer.

3.3. The Influence of Current Density

The enlargement of current density can improve the growth rate of oxidation film and cut down the time that thickness of film needs. However, when current density reach a certain limit, it will get the verse result. Because the excessively high current density will enlarge heat effect in porosity of oxidation film, which cause the dissolution of oxidation film accelerate. Of course, the excessively low current density cannot be allowed, which will widely reduce the growth speed of oxidation film. Practice shows that, it is better to control current density at the range of (0.8~2.5) A/dm², in the process of oxidation process, the fluctuation of current density smaller, the better. On the initial stage of oxidation, the production operation should be implement by the ways that gradually increase current density to specifies in a certain period of time (0.5~2 (min)) [11].

3.4. The Influence of Oxidation Time

Oxidation time should be chosed according to the composition of electrolyte concentration and temperature, current density and thickness of oxide film [12]. In the same cell liquid, if the temperature of electrolyte is lower and current density is higher, the growth speed is quicker, and the oxidation time witch is to get the regulation thickness of oxide film will be shorter and vice versa. In the initial stage, the development of thickness of oxidation film is almost in a straight line up with the time of oxidation, however, as the extent of time, the thickness will gradually reduce its growth, and finally, it will stop. In generally, the oxidation time will not be over 60 min.

3.5. The Influence of Alloy Composition

The aluminum alloy of different components of organization has largely difference in the appearance of the oxidation film. If the purity is more higher, it is easier to get colorlessly, transparently and shiningly decorative oxidation film, whereas, the higher the content of alloy, the lower the transparent and shining of oxidation film and the worse of the corrosion resistance of the oxide film. If the content of copper or silicon of aluminum alloy is higher, anodic oxidation becomes more difficulties [13]. Because of the loose organization, more micro hole defect and uneven organization and other factors of cast aluminum alloy, anodic oxidation should be specially taken care of, or else, it will be easy to dissolve.

3.6. The Main Measurement to Avoid Dissolution Phenomenon

In order to effectively avoid dissolution phenomenon in anodizing, we can take the measurement as follow: (1) choose the promising power and the appropriate current density and current waveform; (2) adapt effectively to quickly loose the heat near the oxide side; (3) choose different additional and current waveform according to different alloy composition; (4) ensure that the contact between artifact and tooling is well and the cathode conductivity is well; (5) the influence of hard anodizing on alloy is greater than conventional hard anodizing. Thus, when hard anodizing, different aluminum alloy parts should avoid the mixed of batch.

4. THE CASE ANALYSIS OF THE PROBLEM OF HARD ANODIZING DISSOLUTION OF ALUMINUM ALLOY PART

Some aviation products of bushing parts’ material is LD10, the entirety of parts is pipe construction, its length is 174 mm and inner diameter is Φ 25.5 mm, the maximum of outside diameter is Φ 30 mm, the thickness of wall of parts is 2.25 mm, The thinnest is 2 mm. In the process of production, the middle sulfuric acid solution is used to adapt constant-voltage method to hard anodize. The highest pressure of film growth process is 60-70 v; the bath temperature is controlled around-5°C. Parts are adopted vertical hanging. The bottom of hard anodized needs to pass the compressed air to mix. In a group of 49 parts of hard anodizing process, 24 dissolved, dissolution mainly occurred in parts of the lower part.

4.1. The Analysis of Causes of Material and Technological Parameter

For this component, since LD10 material is also used in other products, what’s more, the fixed routine, technological
parameter and voltage curve used in the process of hard anodizing is provided automatically by the equipment of power, and not having any problem to the component of other LD10 material, which indicate that there is no problem in the utmost electric tension that choose by LD10 material and boosting process In the process of oxidation is no problem, is reasonable. Thus, boosting process that aim at LD10 material and the process of hard anodizing is no problem, and is not the reason why component dissolve.

4.2. The Analysis of The Phenomenon of Unfair Distribution of Ampere Density

According to the actual place of part dissolute, if the film layer of parts in fixture hanging part is complete and no dissolution phenomenon happened. If fixture hanging part is not secure, it will cause too large inrush current that contact point between parts and fixture and lots of heat was generated. The temperature of part that near sulfuric acid surface heating to add the sulfuric acid solvent make the growth speed greater than hard anodized, after that the film layer is dissolved, matrix metal began dissolve. Thus, the part damage will occur at conductive point location of burn; however, to observe the part of clamping of component, film layer’s surface is complete without the trace of dissolution. Thus, we can get the conclusion that the non strong contact between component and clamping is not the reason that causes current density inhomogeneous and component be broken down.

4.3. The Cause Analysis That Radiating of Parts Local Surface Causes Parts to Dissolve

Because it is a tubular part, using vertical racking during the hard anodizing process, stirring the solution in the parts at the bottom of the bath, which will cause that the cross sectional area of part is too small, so the compressed air from bottom of part cannot be guaranteed to through the hole. Meanwhile, the part in the bath cannot be guaranteed absolutely vertical, which is likely to cause too high temperature of the center hole, the film dissolves faster than grows, and the partial dissolution phenomenon occurs. We can determine the main reason of parts dissolving during the hard anodizing process is the not good from the place and feature dissolution occurred.

One study found that the same parts in the previous production process appear the dissolution phenomenon in the oxidation tank frequently. Comparing the production process of the part with the previous production process, the process parameters, solution components and fixture of the hard anodizing are basically same, the only relatively large change happened is the compressed air agitation lines which is laid at the bottom of existing oxidation tank.

According to the stress analysis, when compressed air stirs the solution, air bubbles move from the bottle of the solution to the surface, which is not vertical but curved. That makes the compressed air not even when it reaches the air line, and there is a big difference between the solution bubble center and the compressed air outlet position. This difference becomes larger and larger with the deepening of cross-sectional area of the solution, which cannot be accurately controlled, resulting in some difficulty to production.

During the actual parts operation, when the parts’ installing and hanging processing is complete, it enters into the hard anodizing tank, the operator usually firstly observe the solution agitation according to the size of the bubble on surface and choose a good stirring position to locate the parts. However, due to the instability of the bubble movement, the liquid surface area of the bubble will change, which will affect the cooling effect of this portion of the part.

From the position of dissolution, it mainly appears in the middle and lower part of parts. This is mainly due to the 100 mm of the distance between the top of the part and the solution surface. Since the bubble continuously arrives to the solution surface and break over and over, the tremendous force that generated by bubble burst plays a stirring action, so the temperature of the shallow level of the liquid is even, the solution of the upper half part of the part continuously flows, and the heat is get neutralized, which has maintained the continued growth of the film, and this is why the upper half of the part does not dissolve.

For hard anodizing bath with larger cross-sectional area and deeper depths, that the compressed air at the bottom of the bath is stirred just makes the bottom of the bank and solution within about 25 mm. But the middle of the solution is poorly stirred, which is not conducive to the parts that has a small horizontal cross-sectional area. When the cross-sectional area of part is large(such as a housing-type parts), that the compressed air moves from the bottom upward will be disturbed by the surface of parts, and the bubble changes the movement direction to improve the fluidity of the solution, which is one of reasons why the housing-type parts are not prone to be dissolved.

4.4. The Measures Taken

For these reasons above, the key to solving such problems is to reduce the temperature of solution surface of the parts. Two mainly measures have been adopted:

(1) Make improvement of existing tooling in Fig. (2), and change the auxiliary cathode rod of the central hole of the parts into hollow tube, then add vent hole at the lower half of the tube wall of the hollow tube, and connect the hollow tube with a compressed air pipe to accelerate the cooling the inner hole of the parts. Since the compressed air at the bottom of the tank rises unstably cannot simply rely on the stirring function of compressed air at the tank bottom.

For these parts, we should change the aluminum stick into hollow aluminum tube which is used during the oxidation process, and block the bottom of the aluminum tube, drill a small hole evenly by 1/3 of scope near the bottom. As auxiliary cathode, it also plays the role of compressing the moving air stirring tube. The aluminum stick is connected with the power cathode, and meanwhile, a plastic hose is used to get through the compressed air of the production line. Thus, the problem of stirring the solution in the parts inner hole during the process of hard anodizing is solved, which avoids the phenomenon of parts dissolution.
Through in-depth analysis of the dissolving phenomenon appearing during hard anodizing process of the aluminum alloy parts, and this paper puts forward ideas and solutions, which has practical significance to solve dissolving phenomenon during the hard anodizing process.

CONFLICT OF INTEREST

The author confirms that this article content has no conflict of interest.

ACKNOWLEDGEMENTS

This work is supported by the Natural Science Research Project of Shanxi Provincial Education Department, China (NO: 2013JK1122), the Education Reform Project of Xi’an International University, China (NO: 2013B47, 2013B18), the Planning Project of Shanxi Provincial Science and Technology Department, China (NO: 2014JM8352).

REFERENCES