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Effect of Aspergillus Niger on Microbial Corrosion of 6063 Aluminum Alloy

Dingzhao Liang

School of Materials Science and Engineering, SUSE University, Zigong 643002, China

Abstract

In recent years, the major economic losses caused by microbial corrosion have received great attention from various countries. Whether it is space shuttle, building doors and windows, or underground pipelines, there is a serious phenomenon of microbial corrosion. How to explore the corrosion mechanism of microorganisms on various alloy materials and find efficient microbial corrosion protection methods is a major problem for researchers. In this paper,surface morphology analysis and electrochemical test data were used to study the corrosion behavior of Aspergillus niger on 6063 aluminum alloy. have close ties.

Keywords

6063 Aluminum Alloy; Aspergillus Niger; Microbial Corrosion; Morphology Analysis; EIS.

1. Introduction

Aluminum alloy materials are widely used in various aviation equipment and building profiles because of their high strength, low density and good mechanical properties. At present, its use is second only to steel[1,2]. 6063 aluminum alloy is a low alloyed Al Mg Si alloy. Because of its excellent heat treatment performance and excellent plasticity, it is favored by building aluminum doors, windows and curtain wall frame materials. According to statistics, 80% of aluminum alloy profiles are made of Al Mg Si alloy, and 70% of them are made of 6063 aluminum alloy[3]. The corrosion resistance of 6063 aluminum alloy in the humid environment is always a serious challenge for the growth of microorganisms in the humid environment, but the corrosion resistance of 6063 aluminum alloy will be brought by the long-term existence of microorganisms. In recent years, researchers have counted the economic losses caused by microbial corrosion. In 2013, the corrosion cost in the United States has reached $2.5 trillion, more than 3.4% of GDP[4]. The economic loss caused by microbial corrosion accounts for about 20%, which has attracted extensive attention of researchers. Researchers' investment in microbial corrosion research is increasing, and it is gradually found that mold is a typical representative of microorganisms that cause the failure of aluminum alloy materials. Mold is the general name of filamentous fungi. It is eukaryote. It is an extremely vigorous aerobic fungus. It mainly propagates by producing spores, which can resist all kinds of harsh environment. The suitable growth temperature range of mold is 20 ~ 40 ℃, and the humidity is more than 70%. If there is sufficient carbon source, nitrogen source and inorganic salt, the spores of mold can grow very fast on the surface of materials. The corrosion mechanism of mold on aluminum alloy materials is a composite performance under the joint action of many factors. Some researchers [5-7] believe that mold will obtain a certain amount of metal elements (such as Zn, Mg, Fe, Cu and other metal elements) from the surface of aluminum alloy materials adsorbed by mold during growth and metabolism, which can promote the dissolution of aluminum alloy, and produce a large number of organic acids during metabolism, including succinic acid, oxalic acid, glutaric acid, glyoxylic acid, pyruvic acid, etc., which can significantly reduce the pH of local corrosive medium and break the oxide film on the surface of aluminum alloy materials, Promote stress corrosion cracking and galvanic corrosion, which can significantly accelerate the

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corrosion failure of aluminum alloy components. Studies have shown that for aluminum alloys the representative mold groups mainly include: Aspergillus spp., Penicillium spp., Alternaria spp., Brevibacterium spp., Cladosporium spp., Trichoderma spp., and the representative molds mainly include: Aspergillus niger, Rhizopus oryzae, Aspergillus oryzae, Aspergillus flavus, Penicillium chrysogenum, Penicillium citri etc[8]. Different kinds of molds, because of the differences in their metabolic activity and corrosion products, lead to different microbial film structures formed by molds on the surface of aluminum alloy materials, and then, the microbial corrosion behaviors and mechanisms of aluminum alloy materials are significantly different. It remains to be further explored for the difference of corrosion behavior of aluminum alloy materials by different molds. In this paper, 6063 aluminum alloy and Aspergillus niger will be selected as research objects, and the corrosion effect of Aspergillus niger on 6063 aluminum alloy will be studied initially.

2. Experiment

2.1. Main Experimental Materials and Instruments

Four block 6063 aluminum alloy hang piece specimens (specification: 12×16×5 mm), two block 6063 aluminum alloy electrochemical specimens (specification: H= 10 mm, Φ= 11 mm), four 500 ml wide mouth flasks, two 500 ml four port flat bottom flasks, 200 ml of Aspergillus niger solution, and four liters of Potato Dextrose Medium. 1 scanning electron microscope (tescan vega-3sbu, Shanghai yongao precision instruments Co., Ltd), The solartron1278 + 1260a electrochemical workstation test for AMETEK.

2.2. Experimental Approach

2.2.1. Hanging Drop Experiments

Four prepared 500 ml wide mouth bottles, 2 l Potato Dextrose Medium, 4 hanging drop coupons, 4 small wood sticks and 4 fine lines of 30 cm length were taken and placed in the mould bench, and ultraviolet sterilization was turned on for 30 min. UV was next turned off, and hanging films for the sterile group were started. Pour 440 ml of Potato Dextrose Medium into each of 2 500 ml wide mouth bottles, put on hanging pieces with fine lines, hang from a small wooden stick stuck at the mouth of the bottle, Hang 1 specimen per wide mouth bottle, and finally seal the mouth of the bottle with breathable parafilm. " sterile-10 days ", " sterile-15 days ". were marked on the wide mouth bottles in turn with a marker pen. Hanging pieces with mycelial groups were next started, 400 ml Potato Dextrose Medium was poured separately in 2 500 ml wide mouth bottles, 40 ml black Aspergillus fluid was injected in each wide mouth bottle with a pipette, similarly 1 test piece was hung from each wide mouth bottle, and the mouth of the bottle was sealed with permeable parafilm. " bacte - rium-10 days ", " bacte - rium-15 days " were marked on the wide mouth bottle in turn with a marker pen. Four wide mouth bottles were placed in a mold incubator, and after incubation to the corresponding time, the hanging pieces were removed, cleaned with clean water, and the surface of the hanging pieces was wiped with cotton balls moistened with 75% alcohol, dried, and the surface morphology of the specimens was observed using a scanning electron microscope.

2.2.2. Electrochemical Experiments

Take 2 prepared 500 ml four port flat bottom flasks, 2 electrochemical test samples, 2 platinum electrodes, 2 reference electrodes, a porous rubber stopper 6, 1 l Potato Dextrose Medium and place in the mold bench to turn on ultraviolet sterilization for 30 min. Turn off the UV, turn on the fan, and prepare to assemble the electrodes. After 1 platinum electrode, 1 reference electrode and 1 electrochemical sample were secured to the peripheral three bottles of the four port flat bottom flask with rubber stoppers so that the reference electrode converged to serve as an electrochemical style for the working electrode, 440 ml Potato Dextrose Medium was

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poured from the middle bottle mouth (note that the medium solution is to completely flood the three electrodes), then the middle bottle mouth was sealed with permeable parafilm and the " electrochemical sterile " was marked with a marker pen. Next the mycorrhizal group electrodes were assembled by the same method, but poured only 400 ml Potato Dextrose Medium, poured again 40 ml black Aspergillus fluid, sealed the middle bottle mouth with a breathable parafilm and marked " electrochemically - with bacteria " by a marker pen. Two four port flat bottom flasks were placed in a mold incubator for 1 day before electrochemical data were tested with an electrochemical workstation.

3. Experimental Results and Analysis

3.1. SEM Morphology and Analysis

The corrosion morphologies of 6063 aluminum alloy specimens immersed in the black Aspergillus fluid for 10 days and 15 days, respectively, were examined by scanning electron microscopy, and the morphologic observations under 1000 to 2000 magnifications are shown in the following figure:

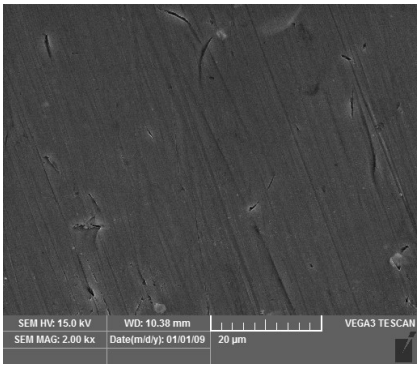

Figure 1. Morphology of 6063 aluminum alloy soaked in sterile solution for 10 d

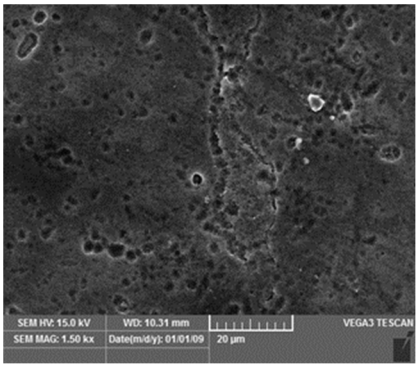

Figure 2. Morphology of 6063 aluminum alloy soaked in A.niger solution for 10 d

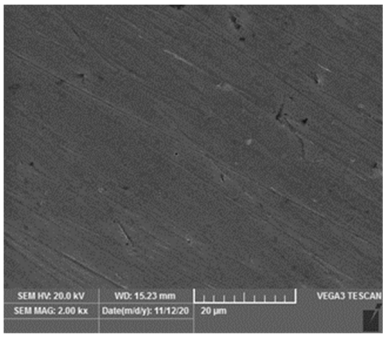

Figure 3. Morphology of 6063 aluminum alloy soaked in sterile solution for 15 d

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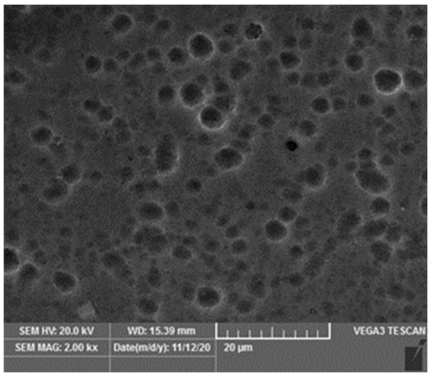

Figure 4. Morphology of 6063 aluminum alloy soaked in A.niger solution for 15 d

Contrasting the morphologies of 6063 Al alloy soaked in the two systems respectively, the surface of Al alloy subjected to Aspergillus niger liquid immersion produced obvious corrosion pits, while the surface of Al alloy subjected to sterile solution immersion was smoother except for some scratches. Comparing figures 2 and 4, it can be found that the depth and number of corrosion pits on the surface of 6063 aluminum alloy increase with the increase of immersion time. The electron micrograph shows that the corrosion pits on the surface of the aluminum alloy are basically round pitting, which fits well with the morphological characteristics of pitting, indicating that the pitting corrosion of 6063 aluminum alloy was promoted by Aspergillus niger. The generation of pitting corrosion on the surface of aluminum alloy should be the result of a combination of factors, and this is closely related to the complex metabolic activity of A. niger. According to the corrosion mechanism of aluminum alloy by mold as mentioned earlier, on the one hand Aspergillus niger adsorbed on aluminum alloy for growth metabolism when it got a certain amount of metal elements from the surface of aluminum alloy, which promoted the partial dissolution of aluminum alloy; On the other hand, Aspergillus niger underwent metabolism on the surface of aluminum alloy to produce a large amount of organic acids, which significantly decreased the local pH value of the corrosion medium and destroyed the oxidative protective layer on the surface of aluminum alloy and promoted corrosion occurrence. Under the combined effect of the two, the speed of pitting corrosion occurred in aluminum alloy increased significantly, resulting in pitting pits densely distributed on the surface of aluminum alloy.

3.2. Electrochemical Test Results and Analysis

3.2.1. Open Circuit Potential

Open circuit potential is generally used in electrochemistry to judge the corrosion propensity of the experimental target inside a system, and the judgment criteria are: the more negative the potential, the greater the corrosion propensity. The open circuit potential changes of 6063 aluminum alloy in sterile solution and Aspergillus niger liquor are shown in Fig 5.

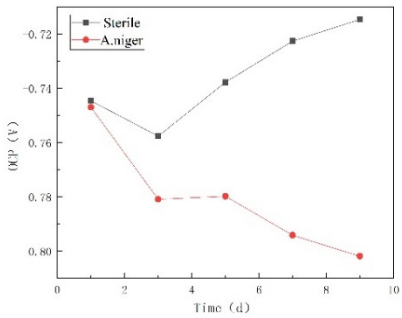

Figure 5. OCP of 6063 aluminum alloy in sterile solution and A.niger solution

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It can be seen from Fig. 5 that the general trend of the open circuit potential of 6063 aluminum alloy in sterile systems is rising, i.e. the corrosion tendency is getting smaller and smaller. From day 1 to day 3, the open circuit potential in the sterile system showed a decreasing trend, and there was partial oxygen in the solution, prompting the aluminum alloy to undergo the oxygen absorption reaction, which reflects a certain corrosion tendency; From 3rd to 9th days, the open circuit potential showed an upward trend, the oxygen in the solution was exhausted, and the corrosion tendency gradually decreased. While the overall open circuit potential of aluminum alloys in the liquid system of Aspergillus niger showed a decreasing trend, with an increasing corrosion tendency. From day 1 to day 3, the open circuit potential decreased rapidly, Aspergillus niger propagated on the surface of aluminum alloys, performed growth metabolism, produced a large number of organic acids, promoted the occurrence of hydrogen evolution reaction on the surface of aluminum alloys, corrosion tendency intensified; From day 3 to day 9, the decreasing trend of the open circuit potential in the aerobic system slowed, the propagation of Aspergillus niger on the surface of aluminum alloys tended to be saturated, the production of organic acids somewhat reduced, and Aspergillus niger produced a layer of microbial film on the surface of aluminum alloys, which blocked the contact between oxygen and aluminum alloys, the oxygen absorption reaction was inhibited, and the corrosion tendency somewhat slowed.

3.2.2. Electrochemical Impedance Spectroscopy

The electrochemical impedance spectroscopy and equivalent circuit are used to study the corrosion behavior of aluminum alloys in bacterial fluid, and relatively intuitive results can be obtained. 6 and 7 are the results after fitting the electrochemical impedance spectra of 6063 aluminum alloy in sterile solution and Aspergillus niger liquor by using zview software.

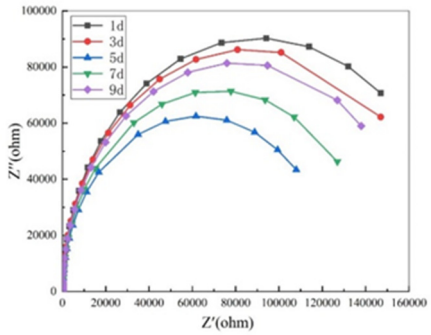

Figure 6. Fitting EIS of 6063 aluminum alloy in sterile system

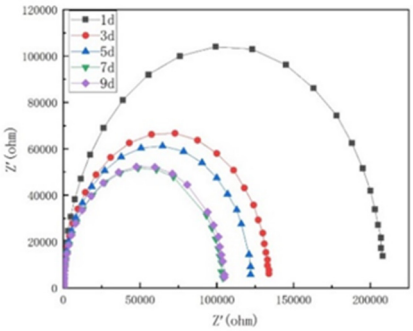

Figure 7. Fitting EIS of 6063 aluminum alloy in A.niger system

From Fig 6, it can be seen that from day 1 to day 3, and then to day 5, the capacitive loop in the aseptic system decreases gradually, and it decreases to the minimum at day 5, indicating that the aluminum alloy under this system shows a certain corrosion tendency, that is, the aluminum

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alloy enters the corrosion state by reacting with the oxygen in the solution, and the corrosion of the aluminum alloy reaches the peak at day 5. From day 5 to day 7 and then to day 9, the capacitive loop increases gradually, the corrosion tendency of aluminum alloys decreases gradually, aluminum alloys enter the passivation state, and the corrosion is inhibited. Fig 7 shows that the capacitive loop in the liquid system of A. niger from day 1 to day 9 is constantly decreasing, indicating that the corrosion propensity of aluminum alloys under this system is gradually increasing. The capacitive loops of the 3rd, 5th, 7th, and 9th days are much smaller than those of the 1st day, which indicates that in the early immersion period, Aspergillus niger growth and reproduction on the surface of aluminum alloy is extremely vigorous, produces a large amount of organic acids, accelerates the cathodic reaction hydrogen evolution reaction in the corrosion reaction of aluminum alloy, and aggravates the corrosion of aluminum alloy. However, the magnitude of capacitive arc reduction on the 3rd, 5th, 7th, and 9th days is small, and the corrosion tendency of aluminum alloy is slowed down, because Aspergillus niger produces a layer of corrosion product film on the surface of aluminum alloy, which reduces the contact area between aluminum alloy and oxygen and has a certain inhibition on the corrosion of aluminum alloy surface. Comparing Fig. 6 and Fig 7, it is obvious that the capacitive loop in the germ free system is much smaller than that in the germ free system, that is, the corrosion tendency of aluminum alloy under the germ free system is larger. The conclusions of figures 6 and 7 fit well with those drawn earlier from Figure 5.

3.2.3. Polarization Curve

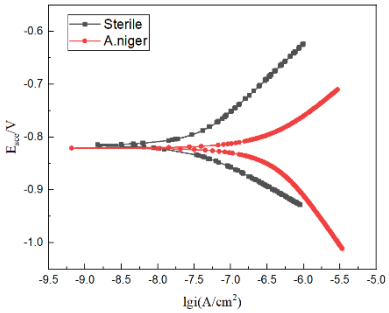

Figure 8. Polarization curves of 6063 aluminum alloy in A.niger and sterile systems

Testing the polarization curves of corroded metals is an important method to explore the laws and mechanisms of corrosion behavior of metals. The polarization curves of 6063 aluminum alloy in both sterile and bactericidal systems were tested in this experiment using the solartron1278 + 1260a electrochemical workstation of AMETEK, followed by corrview3 10 the software fitted the test results and the results are shown in Fig 8. The software fitting yields a corrosion potential E_0 = -0.81538 (V) for aluminum alloy under aseptic system and a corrosion current I_0 = 3.4985 × 10^{-8} (Amp/cm^{-2}); Corrosion potential E_0 = -0.82065 (V) and corrosion current I0 = 3.7837 × 10-7 (Amp/cm-2) of aluminum alloy under bacteriological system. While the corrosion potential of aluminum alloys in the germ free system is much greater than that in the germ free system. Neglecting the very similar corrosion potential, the larger the corrosion current, the more severe the corrosion. Comparing the corrosion currents of aluminum alloy under the two systems, it shows that Aspergillus niger can greatly promote the corrosion of 6063 aluminum alloy.

4. Conclusion

The comprehensive analysis of the obtained results from SEM topography, open circuit potential mapping, electrochemical impedance spectroscopy and polarization curves lead to the following conclusions: (1) Aspergillus niger can promote the strong corrosion of 6063

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aluminum alloy. (2) The corrosion induced by Aspergillus niger on 6063 aluminum alloy was dominated by pitting corrosion. (3) The promoting effect of Aspergillus niger on the corrosion of 6063 aluminum alloy is limited by its growth and propagation rate, the faster the propagation rate, the stronger the effect of promoting the corrosion; The slower the propagation rate, the weaker the contribution to promoting corrosion.

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References

[1] Reboul M C, Baroux B: Metallurgical aspects of corrosion resis-tance of aluminium alloys . Mater. Corros, (2011), p.62: 215.

[2] Arrabal R, Mingo B, Pardo A, et al: Pitting corrosion of rheocastA356 aluminium alloy in 3.5wt.% NaCl solution . Corros. Sci.,(2013), p.73: 342.

[3] Nie Cunzhong, Zhang Houan: Mechanical properties of 6063 aluminum alloy profile . Light Alloy processing technology, (1993) No.3: p.29-34.

[4] National Association of Corrosion Engineers. National Association of Corrosion Engineers international IMPACT study. (2017-04-13). http://impact.nace.org/executive-summary. Aspx.

[5] Miecinskas P, Leinartas K, Uksiene V, et al: QCM study of micro-biological activity during long-term exposure to atmosphere--alu-minium colonisation by Aspergillus Niger . J. Solid State Elec-trochem, (2007), p.11: 909.

[6] Corvo F, Jiron-Lazos U, de la Rosa S, et al: Aluminum and anod-ized aluminum biocorrosion caused by Aspergillus niger . Mex-ico, p.2016: 9964.

[7] De Leo F, Campanella G, Proverbio E, et al: Laboratory tests offungal biocorrosion of unbonded lubricated post-tensioned tendons. Constr. Build. Mater., (2013), p.49: 821.

[8] Zhang Jiangtao, Wu longyi: Mold protection design of airborne equipment . Equipment environmental engineering, Vol. 4 (2007) No.6. p.70.