

ELECTROCHEMICAL BEHAVIOUR OF THE 1579 Al ALLOY WITH WELDED JOINT: CORROSION FEATURES AND COATING PROTECTION

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Abstract: The electrochemical activity, as well as the peculiarities of corrosion process on the surface of the 1579 aluminium alloy with welded joint area, were investigated using Scanning Vibrating Electrode Technique (SVET) and Scanning Ion-Selective Electrode Technique (SIET) in 3% NaCl. It was established that corrosion evolution occurred along the weld interface. Methods of anticorrosion protection based on plasma electrolytic oxidation (PEO) were suggested in this work. Electrochemical behaviour on the microscale level of aluminium alloy with and without protective layers was described. Composite polymer-containing coatings provide the Al alloy with the best anticorrosion protection and improve the corrosion resistance of the material in the aggressive chloride-containing environment.

Keywords: Aluminium alloy; weld interface; SVET; SIET; protective coatings

INTRODUCTION

In the recent times, Al alloys are widely used in various areas of science and technology. Al alloys are popular material to be applied in such fields as automobile, aerospace and marine construction. At the same time, the presence of the intermetallic particles and phases with different electrode potential in the aluminium alloys makes such materials highly susceptible to localized corrosion, especially in the marine environment (1–3).

For the industrial implementation of aluminium alloys, it is necessary to protect these materials against corrosion. There are different ways to generate a protective and anticorrosion layer on the Al alloy surface and plasma electrolytic oxidation (PEO) method is one of the most challenging one (4–13).

Recently, to increase the corrosion resistance of the PEO-coating the method of composite polymer-containing layer formation via superdispersed polytetrafluoroethylene (SPTFE) treatment was proposed (14,15). SPTFE treatment can be used to increase the Al alloy anticorrosion protection. The use of SPTFE makes a reliable barrier by means of PEO pores sealing and therefore the ions penetration to the surface of the substrate reduce (14,15).

The way of anticorrosion layer generation on the 1579 Al alloy surface was proposed in this work. The polymer treated PEO-layer provides the Al alloy with high anticorrosion protection. The anticorrosion and electrochemical behaviour of the formed coatings were examined.

In accordance with previous works (4,16–19), the modern informative methods to study the local features of the corrosion include scanning electrochemical techniques

(11,20–26), such as Scanning Ion-Selective Electrode Technique (SIET) and Scanning Vibrating Electrode Technique (SVET).

The study of the corrosion on the 1579 aluminium alloy surface with welded joint area by means of localized methods is presented. The formation and study of composite PEO-coating on the sample surface, which improves protective properties of the material, have been provided as well.

MATERIALS AND METHODS

Samples

The 1579 Al alloy (including the welded joint) (6.701 wt. % Mg; 0.639 wt. % Zn; 0.138 wt. % Cu; 0.548 wt. % Mn; 0.150 wt. % Fe; 0.126 wt. % Zr; 0.107 wt. % Sc; 0.116 wt. % Cr; 0.095 wt. % Ni; 0.021 wt. % Ti; balance – Al) was a specimen for study.

The PEO-layer was obtained on the Al alloy surface at 0.5 A/cm^2 . The electrolyte for PEO consists of NaF and $\text{C}_4\text{H}_4\text{O}_6\text{K}_2 \cdot 0.5\text{H}_2\text{O}$, 0.3 g/l and 15 g/l, respectively. The oxidation time was about 160 s. The PEO-layer thickness was 11 μm .

To improve the anticorrosion behaviour of PEO-coating the subsequent treatment of the surface using Forum® SPTFE was made. The procedure of polymer-containing layer generation, proposed in this work, was presented in our works (14,15). 20 wt. % SPTFE suspension in the ethanol was used. The period of sample immersion in the suspension was 25-35 s. Then the material was dried at 26 °C for 1 hour. The time and temperature of sample treatment with the polymer after immersion were 30 minutes and 320 °C, correspondingly.

Electrochemical Measurements

The corrosion process development on the welded joint surface of the Al alloy as well as the anticorrosion properties upgrade after generation of the composite coating were studied using SVET – SIET equipment (Applicable Electronics, USA).

The typical SVET probe made from Pt–Ir insulated wire covered with a Pt black was used. The distance between the surface of the investigated material and SVET probe was 100 μm . The SVET probe amplitude of vibration was about 17 μm . The SIET pH electrode was used in this work. The SIET microelectrode membrane was defined previously (22). The pH electrode was backfilled with 0.01 M KH_2PO_4 in 0.1 M KCl. The distance between the SIET pH electrode and specimen surface was 40 μm . Specimens were tested in 3% NaCl solution under open circuit potential.

RESULTS AND DISCUSSION

Figure 1 shows the optical image of the studied welded joint zone before SVET-SIET tests. This investigated zone is framed (Fig. 1). After 0.5 hours of the specimen immersion, the corrosion process started. The anodic area on the welded joint zone was generated. Hydrolysis of the Al alloy sample reduced pH in the anodic area. This reaction acidifies the solution and increases the corrosion of the material (26).

Corrosion process development from the edge of the studied zone to the bulk layers of the weld interface was detected by SVET and SIET during the sample immersion from 1.5 to 9 hours (Fig. 2(a)). Intensive corrosion processes occurred at the weld interface in accordance with the SVET-SIET data. The reason for a high

electrochemical activity of the welded joint is connected with microdefects in the morphological structure. Therefore, in the welded joint zone, there are areas with different potential, which lead to the development of the corrosion process.

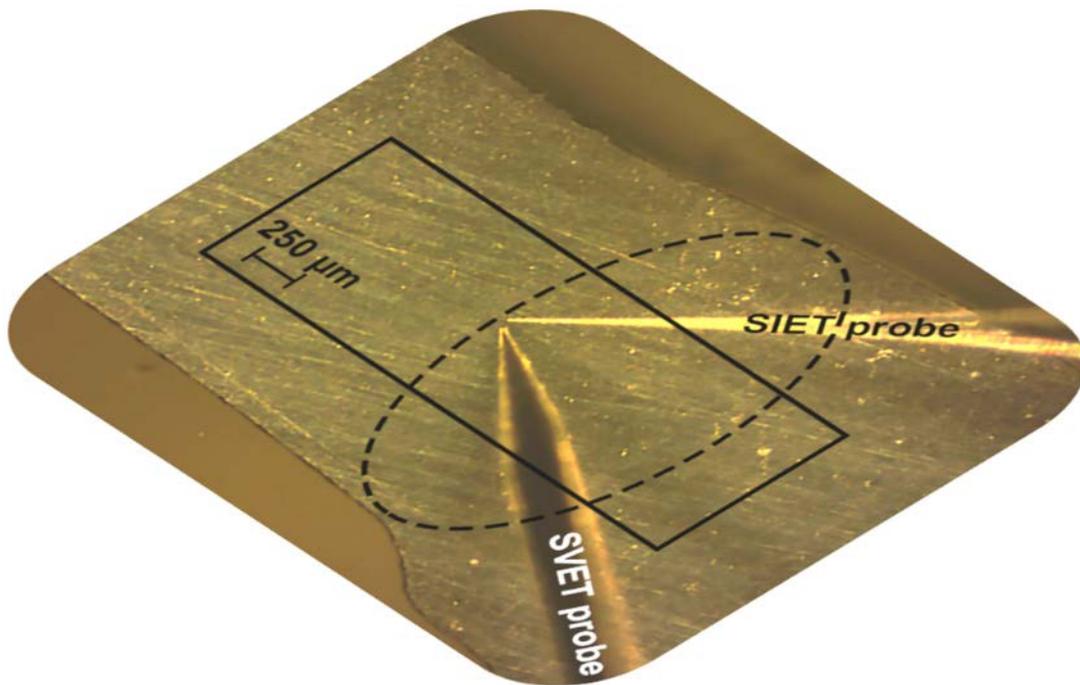


Figure 1. The optical image of the Al alloy specimen with welded joint zone before SVET-SIET measurements. The weld interface is limited by dashed line.

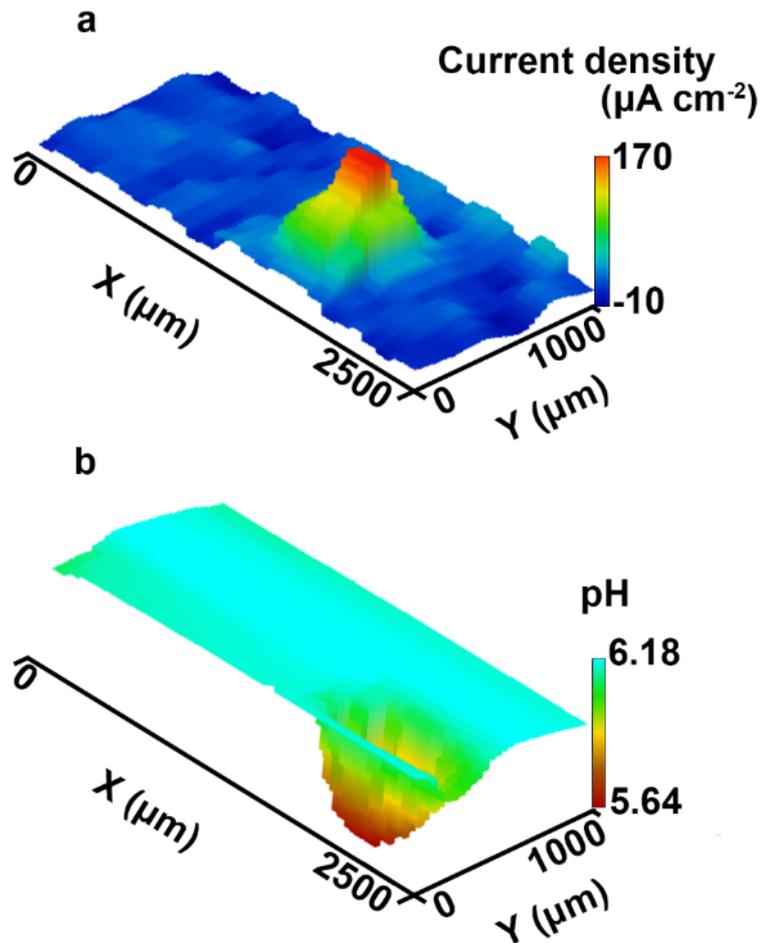


Figure 2. 3D distribution of the current density (a) and pH (b) on the surface of the Al alloy (including welded joint zone) after specimen immersion for 9 hours in 3% NaCl. It was established that welded joint zone under the influence of chloride environment, increased the corrosion destruction of the investigated specimen. Thereby, it is necessary to make an anticorrosion protection of Al alloy.

Rapid corrosion was detected by SVET-SIET methods in the bulk layers of the welded joint area after sample immersion in the chloride-containing medium for 9 hours (Fig. 2(a) and 2(b)). In the anodic zone, the current density maximum reached $170 \mu\text{A/cm}^2$. The pH in this zone reduced down to 5.6 (Fig. 2(b)). Analysis of the SVET-SIET data indicates that welded joint zone of 1579 Al alloy was the area where the high corrosion passed.

The optical image of the studied surface after SPTFE treatment of the PEO-layer is presented in the Fig.3. The studied area is framed. It was established that corrosion activity of the polymer treated specimen did not change during the experimental time. Therefore, SVET-SIET data presented after 500 hours of specimen exposure to 3% NaCl solution. The SVET-SIET methods detected small electrochemical changes on the surface of the specimen (Fig. 4). The welded joint area became a cathodic one after polymer-containing layer generation.

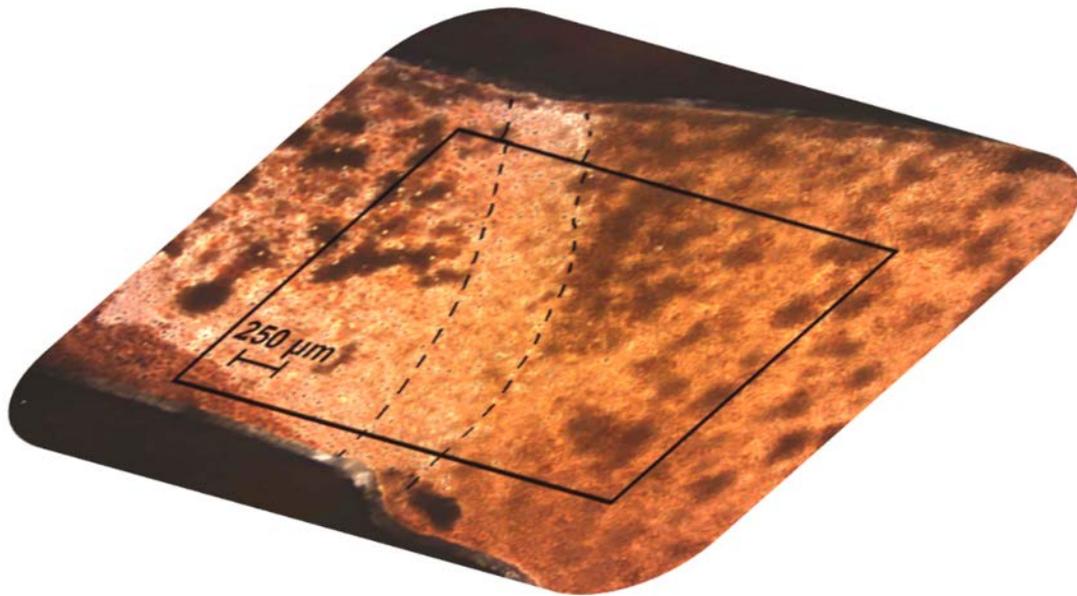


Figure 3. The optical image of the Al alloy specimen with welded joint zone after 500 hours of the material exposure. The weld interface is indicated by dashed line.

Analysis of the SVET-SIET data reveals the different electrochemical processes passing on the specimen surface. Microdefects in the welded joint zone are the reason for the corrosion activity evolution, which was established by SVET-SIET methods. After composite coating generation, these microdefects were covered, and therefore, the weld interface turns into cathodic zone (Fig. 4). The low anodic activity (the current density equalled to $3 \mu\text{A}/\text{cm}^2$) was registered on the specimen surface (Fig. 4(a)).

Unopened pores in the formed surface layers, which is a specificity of PEO-coatings (14–16,27–30), caused the presence of the low anodic activity on the surface of the material. The current density gradient after formation of the composite layer decreased from $180 \mu\text{A}/\text{cm}^2$ (9 hours) (Fig. 2(a)) down to $11 \mu\text{A}/\text{cm}^2$ (500 hours) (Fig. 4(a)). The weld interface was also detected by SIET as a cathodic zone (Fig. 4(b)). The reaction of oxygen reduction is a reason for a high pH in the cathodic zone (26). The pH level in cathodic and anodic areas moved to alkaline values after composite layer formation (8.2 and 8.1 for the composite coating (Fig. 4(b)), 6.2 and 5.6 for the bare material (Fig. 2(b)). This effect is connected with inhibition of the corrosion process by means of the composite coating, thus revealing the high anticorrosion properties of the polymer treated material.

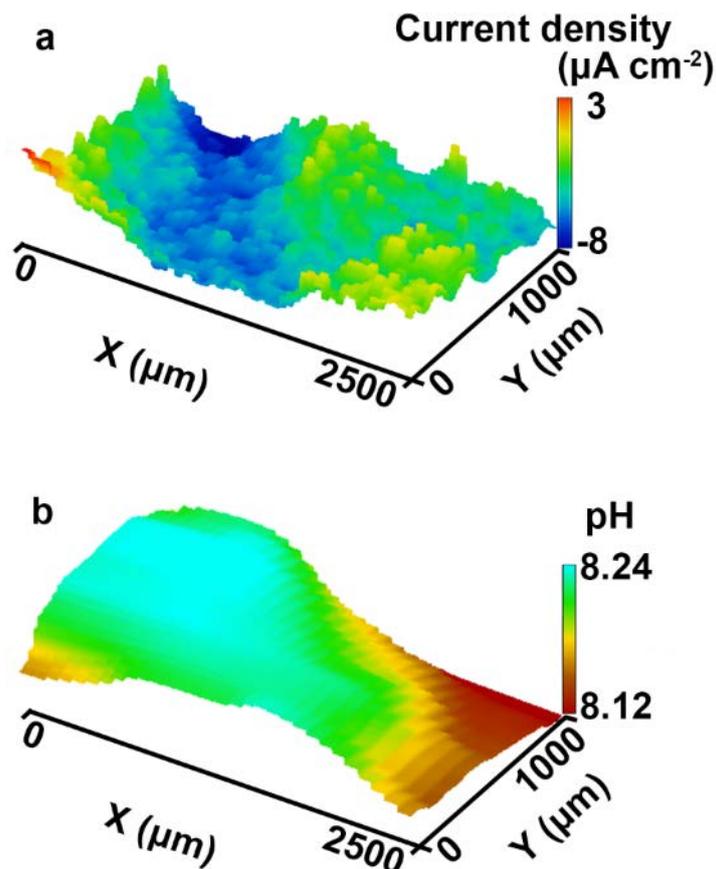


Figure 4. 3D distribution of the current density (a) and pH (b) on the surface of the Al alloy (including welded joint zone) after specimen immersion for 500 hours in 3% NaCl.

This result showed that PEO and polymer treatment provides a significant protection of the Al alloy specimen against the corrosive influence. Such layers inhibit the corrosion process on the studied sample surface. The weld interface turned into cathodic area, and the corrosion stability of the material improved.

CONCLUSION

Specificity of the 1579 Al alloy corrosion was studied. Corrosion process passing along the weld interface was detected by SVET-SIET techniques. Microdefects in the material structure of the welded joint area are the reason for its high electrochemical activity.

The composite coating decreases the corrosion degradation of the sample. Values of the current density gradient for the Al alloy specimen reduced from $180 \mu\text{A}/\text{cm}^2$ down to $11 \mu\text{A}/\text{cm}^2$ due to PEO and SPTFE protection. Such methods make it possible to upgrade the anticorrosion properties of the 1579 Al alloy (including welded joint area) in accordance with the SVET-SIET results.

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