

Research on Corrosion Control Factors of 2A02 Aluminum Alloy of Different States before and after Laser-Shock-Processing

Yongfeng Ren^{1,2}, Lingfeng Zhang^{1,2*}, Yi Xiong^{1,2} and Fengzhang Ren^{1,2}

¹Henan University of Science and Technology, Luoyang 471003

²Henan collaborative innovation centre of Non-Ferrous generic technology, Luoyang 471003

* Tel: 0372-64231269; E-mail: zh_lingfeng@163.com

Abstract. The variation of corrosion behaviors and microstructure of 2A02Aluminum alloy before and after Laser Shock Processing (LSP) were analyzed, and the effects of LSP on corrosion resistance of the alloy were explored. The results show that the corrosion resistance of aluminum alloys with different aging conditions is quite different before and after laser shock. The corrosion potentials of the aluminum alloys with different aging conditions vary with the initial state, the natural aging state, the two aging stages (150°C/6h, 190°C/6h, 8h+160°C/6h), indicating that the grain size and morphology and distribution of precipitated phase under different aging conditions before impact are the main controlling factors in the process of corrosion. The micro-analysis revealed that LSP can form a compact strengthened layer at the surface of the material and can refine grains; at this point the strengthening effect caused by LSP was the main controlling factor in the corrosion process.

1. Introduction

Aluminum alloy has the advantages of low density, high strength, easy forming, corrosion resistance and high conductivity, high thermal conductivity. It has been widely used in the current engineering field [1]. However, in practical applications, aluminum alloy parts are often corroded due to different working conditions which seriously affect their service life [2-4]. It requires that the aluminum alloy not only has excellent mechanical properties, but also should have good corrosion resistance [5-7].

Laser Shock Processing (LSP) is a new technique for strengthening the surface of materials under the impact of super-high strain rate ($10^6\text{s}^{-1} \sim 10^7\text{s}^{-1}$) [8-10]. After the treatment, the mechanical properties of materials and corrosion can be significantly improved which makes them being more widely used [11-13].

In this paper, it discusses the roles of Laser-Shock-Processing in the corrosion protection of aluminum alloy, and provides a new method of application and basis by examining the corrosion behavior of aluminum alloy with different heat treatment before and after laser shock and analyzing the factors that play a leading role in the corrosion process.

2. Experimental materials and methods

The hot rolled state 2A02 aluminum alloy was used as the experimental material. The initial thickness of the sheet was 2mm, and the chemical composition was shown in table 1. The sheet was cut into 15*15*2 mm specimens. After 500°C solution for 2h, they were subjected to natural aging and artificial aging at 150°C/6h, 190°C/6h, 120°C/8h+160°C/6h respectively. And then the treatment of laser shock processing was processed.



Table 1. Chemical composition of 2A02aluminum alloy (wt%)

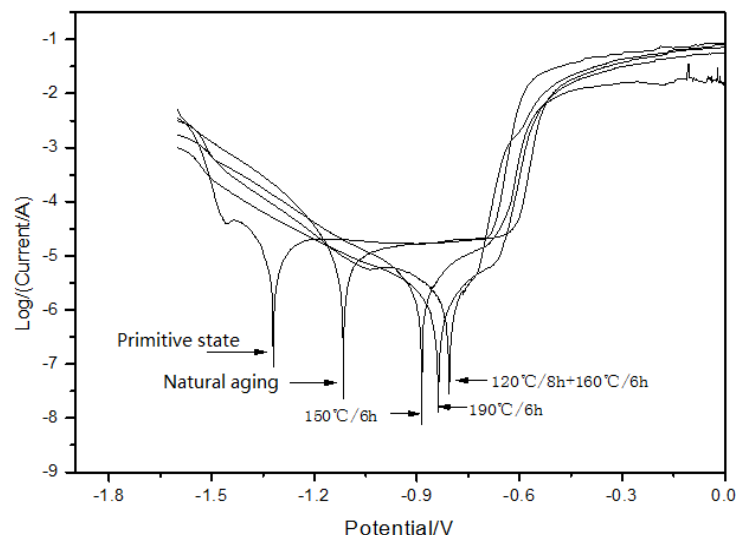
Cu	Mg	Mn	Si	Ti	Al
2.6~3.0	2.0~2.4	0.4~0.7	≤0.30	≤0.15	Bal.

Laser impulse experiments were carried out using imported neodymium glass pulsed lasers from the School of Mechanical Engineering, Jiangsu University. The laser pulse quantity was 26J, the wavelength was 1064nm, the power density was greater than 10^9W/cm^2 , the pulse width was 10ns and the spot diameter was 3mm. Using water with thickness of 1~2mm as the constraint layer, the aluminum foil with a thickness of 0.1mm was the absorption layer. The electrochemical measurements were performed on a CHI660C electrochemical workstation with an experimental temperature of $(25 \pm 5)^\circ\text{C}$, a sample working area of 1 cm^2 , and a 3.5% NaCl solution in electrolyte. The polarization curve was measured at a constant potential of 5mv/s.

The samples of 2A02 aluminum alloy with two-stage aging state were soaked respectively before and after the laser shock and the changes of corrosion morphology were analyzed. The size of the sample is $15 \times 15 \times 2 \text{ mm}$. First, mechanical polish was done. Then it was washed with alcohol. After soaking 1h in 3.5%NaCl solution, the sample was removed and the corrosion product was cleaned up with 80°C 2% CrO_3 +5% H_3PO_4 solution. Finally, it was washed with alcohol. Using JSM5610LV scanning electron microscope to observe the morphology of the corrosion.

3. Experimental results and analysis

The polarization curves of the aluminum alloy after different heat treatments had been shown in figure 1. It can be seen from the figure that the self-corrosion potential varies with the original state, the natural aging state, $150^\circ\text{C}/6\text{h}$, $190^\circ\text{C}/6\text{h}$, $120^\circ\text{C}/8\text{h}+160^\circ\text{C}/6\text{h}$ followed by increased, that is, potential more positive. It is found that the self-corrosion potential of two-stage aging is more positive than that of natural aging and single-stage aging. The self-corrosion potential difference of two-stage aging is relatively small, while the self-corrosion potential difference of single stage and natural aging is relatively large.

**Figure 1.** Polarization curve of aluminum alloy at different ageing states

The corrosion performance of 2A02 aluminum alloy is related to many factors. Since this experiment made different aging treatments for 2A02 aluminum alloy, the grain size and uniformity, the morphology and distribution of precipitation hardening phase are the major factors resulting of the differences in the corrosion performance of 2A02 aluminum alloy. In general, when the precipitated phase is continuously dispersed and distributed in the crystal and the number is large, the precipitation phase will hinder the progress of the material corrosion process [14, 15]. When the precipitates are

distributed in the grain boundaries, the number is small, and the distribution is discontinuous, the galvanic corrosion effect is enhanced and material corrosion is more serious [16].

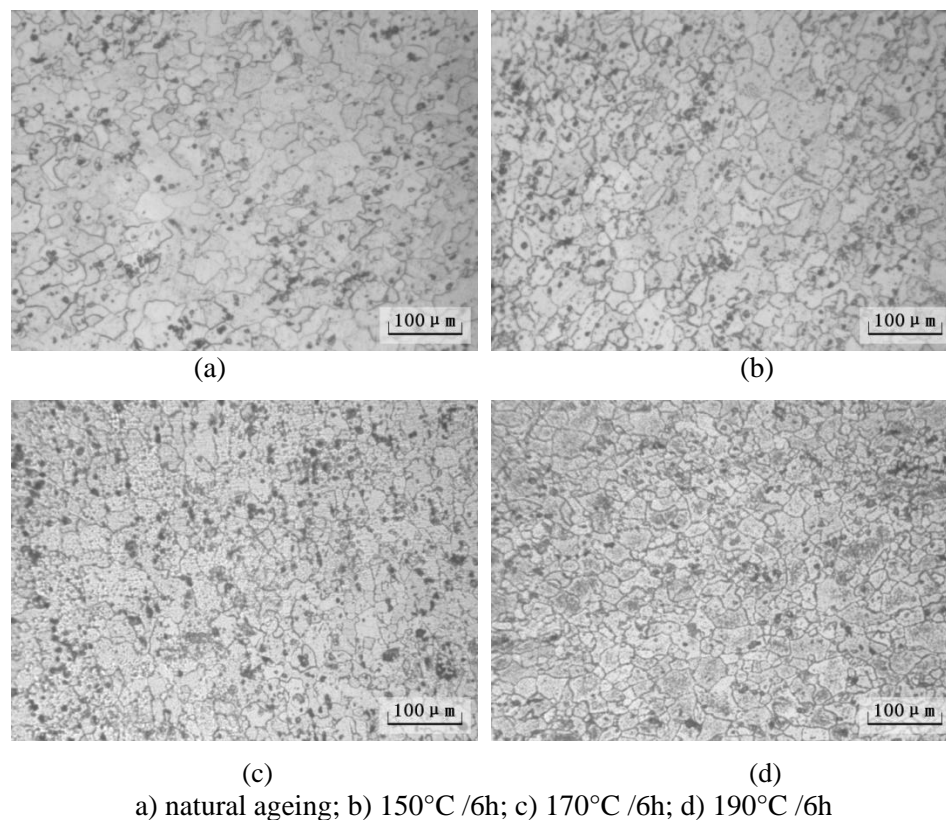


Figure 2. Intergranular corrosion morphology of 2A02 aluminum alloy at different ageing states

According to the principle of passivating film protection [17], it is known that the precipitated phase has a high self-corrosion potential, and generally acts as an electrode. If the stability of the precipitated phase is high, the oxide film formed on its surface is also more stable than that of the substrate, thus preventing corrosion.

Figure 2 shows the microstructure of the aluminum alloy obtained after different aging temperature and time. As can be seen from the figure, naturally aged aluminum alloy has fewer amounts of intragranular precipitation phase and poor grain uniformity and as the aging temperature increases, the grain tends to refine and the size uniformity is better. Compared with figure 1, the corrosion resistance can be improved.

Figure 3 shows the polarization curve of the alloy after laser shock. As can be seen from the figure, the shapes of the polarization curves of the 2A02 aluminum alloy under different aging states are basically the same after being impacted by the laser. Combined with the polarization curves of the alloy without the laser shock, the self-corrosion potential of different aging alloys has varying degrees of positive shift.

However, by comparing the corrosion performance of each aging state after the laser shock in figure 3, it is found that the corrosion performance after the laser shock is similar irrespective of the original aging state structure, and both the corrosion potential and the corrosion current are at extremely similar levels. It is indicated that the strengthening effect caused by laser shock conceals the influence of the difference of heat treatment structure on the corrosion performance, thus it becomes the main controlling factor.

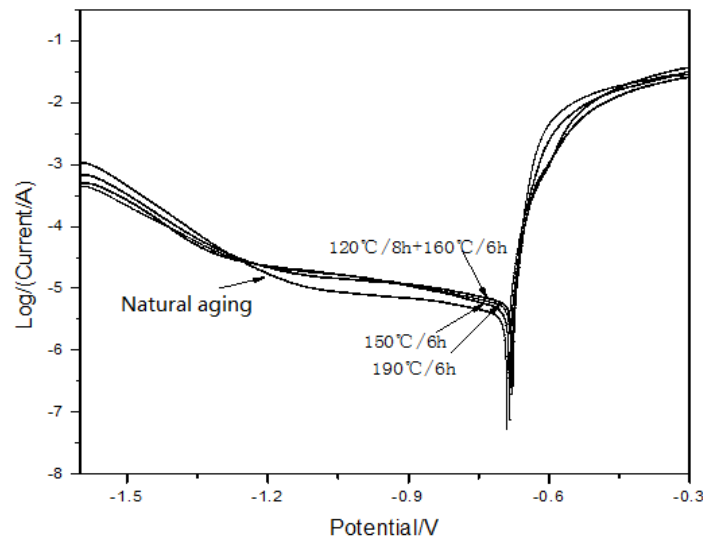


Figure 3. Polarization curves of 2A02 alloy by single LSP in 3.5%NaCl solution

The results of Immersion test micrographs of 2A02 alloy before and after LSP was shown in Figure 4. As can be seen from Figure 4 (a), after the soaking of the two-stage aged aluminum alloy, there are more serious corrosion pits on the surface, which are mainly characterized by pitting corrosion. It is indicated that even if the two-stage aging improves the uniformity of the aluminum alloy, the local corrosion characteristics are still obvious, and there is a strong intergranular corrosion behavior.

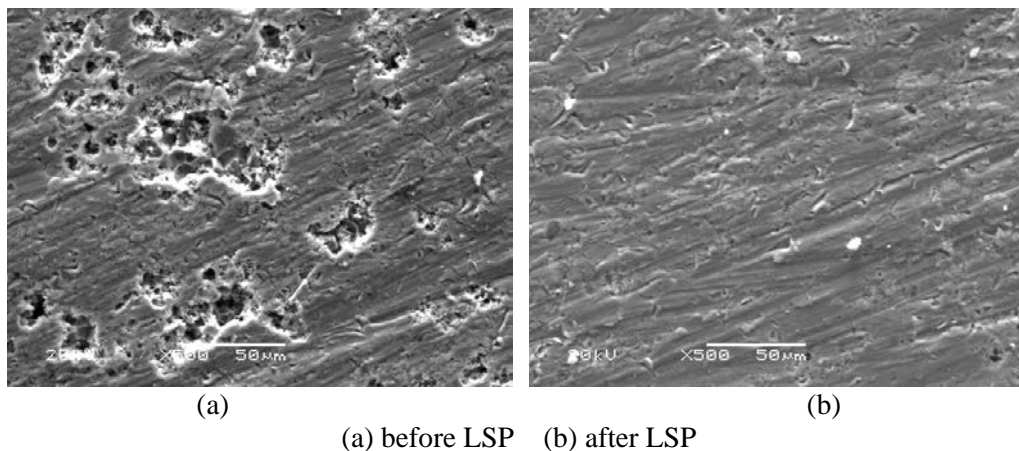


Figure 4. Immersion test micrographs of 2A02 alloy before and after LSP

The intergranular corrosion of aluminum alloy is mainly due to the potential difference between the precipitates and the substrate [17]. When the precipitated phase is located at the grain boundary and is continuously distributed, the intergranular corrosion tendency of the material is larger. On the contrary, when the continuity of the precipitated phase is interrupted, such as dispersion in the intracrystalline distribution, intergranular corrosion tends to be smaller [17]. The way of aging treatment determined the continuous distribution of precipitates in the grain boundary. Therefore, it is easy to produce intergranular corrosion [18], while the laser shock process changes the grain structure formed by aging, which changes the corrosion characteristics. After the laser shock processing, the main corrosion characteristics of the alloy are mainly uniform corrosion, and the corrosion morphology is shallow and small, indicating that the corrosion resistance of the material was enhanced, as shown in Figure 4 (b).

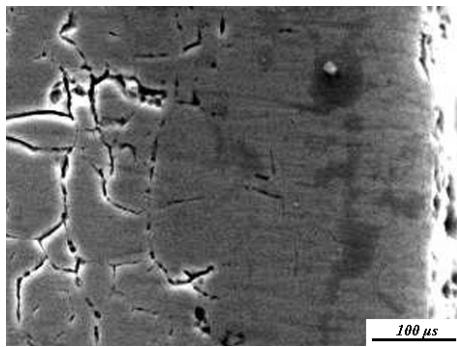


Figure 5. Corrosion characteristics of two stage aged aluminum alloy after laser shock (cross section)

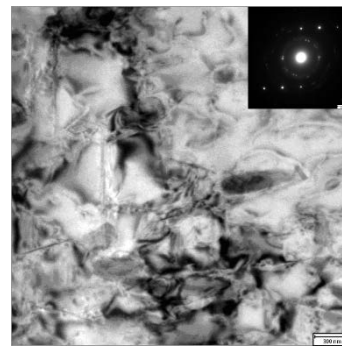


Figure 6. Microstructure and electron diffraction characteristics of shock layer of aluminum alloy after laser shock

After the laser shock is applied to the two-stage aging 2A02 aluminum alloy, the shock zone was cut longitudinally, and the section is deeply corroded. The corrosion depth of the alloy in depth direction is observed, as shown in figure 5. It is found that the depth of the laser shock strengthening layer is about 200 μm , and the corrosion resistance ability is obviously improved. The obvious grain boundary corrosion can be seen outside the laser zone, and the grain boundary corrosion is suppressed in the laser zone.

The alloy after the laser shock is thinned from the back single side. The microstructure of the strengthening layer is observed. The microstructure and electron diffraction pattern shown in Figure 6 show that the main microstructures in the strengthening layer are high density dislocation and gradually transform to sub grain. From the selected area electron diffraction pattern of the corresponding area in figure 6, it can be seen that the diffraction patterns are concentric circles with different radii, indicating that the polycrystalline diffracting ring at the large-angle grain boundaries in the selected area is mainly composed of a large number of different small grains. The confusion degree of 2A02 aluminum alloy crystal orientation increases with the decrease of grain size, the effect of grain boundary in the corrosion process is greatly weakened, the homogeneity of the microstructure is obviously improved, and the strengthening effect brought by the microcrystallization of the crystal structure rises to the main control factor in the process of corrosion, which also shows that the corrosion resistance of the laser has basically the same under the impact of laser no matter what the aging state before and after the laser shock.

4. Conclusions

1) The main controlling factors of the different aged aluminum alloys in the corrosion process are the grain size and the morphology and distribution of the second phase. The corrosion resistance is enhanced with the increase of the homogenization degree of the grain size and the increase of the number of the second phase.

2) After laser shock, the main controlling factor is the size of the grain, and the strong crystallization effect conceals the effect of aging structure on the corrosion performance, so that the corrosion resistance of the different effective aluminum alloys tends to be consistent.

3) The laser shock process forms a strengthening layer of about 200 μm on the surface of the aluminum alloy, and the grains in the strengthening layer are refined to form the microcrystalline substructure.

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6. References

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