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Effect of Polarization on SCC of 7075 Aluminum Alloys

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Abstract

The behavior of stress corrosion cracking (SCC) of 7075 aluminum alloys with different heat treatments had been tested at various polarization potentials with slow strain rate tension (SSRT) method. The results suggest that from the applied -1200mV to -735mV (vs. SCE), the SCC susceptibilities of AA7075 would increase in both anodic and cathodic polarization. And they would increase with the polarization potential in the anodic direction. But at a certain potential, the SCC susceptibilities were different among the alloys. The electrochemical protection is unsuitable to avoid the SCC of 7075 alloy, because both the anodic dissolution and the hydrogen effect play important roles during SCC.

1. Introduction

High-strength aluminum alloys are considered to be promising structural materials in aerospace industry because of their excellent combination of low density, high strength and good corrosion resistance. Hydrogen is able to promote the stress corrosion cracking of 7xxx series aluminium alloys, which indicates that the hydrogen effect is one of the main factors during SCC [1-3]. The purpose of this study was to analyze the hydrogen effects of 7075 aluminum alloys with different heat treatments, and to discuss the SCC mechanism of these alloys.

2. Experimental

2.1 Materials and Heat Treatments

The material was a 76-mm thick plate of commercial AA7075 subjected to T7351 temper, the chemical compositions(mass%) of which is 5.85 Zn, 2.57 Mg, 1.50 Cu, 0.16 Fe, 0.06 Si, 0.05 Mn, 0.21 Cr, 0.02 Ti and balance aluminum. For T6 temper, the raw material was first solutionized at 465℃ for 30 min, quenched in the cool water and then aged at 120℃ for 24h. For retrogression and re-ageing (RRA), the alloy with T6 temper was retrogressed at 203℃ for 10min and then reaged at 120℃ for 24h.

2.2 Stress Corrosion Tests

The slow strain rate tension (SSRT) tests were performed at the free-corrosion potential in an aqueous solution of 3.5 mass% NaCl at 35±1℃. The free-corrosion potential was recorded using a monitor. The strain rate was $9.68\times10^{-7}s^{-1}$. Contrast tests were carried out in dry air. The SCC susceptibilities of all tempers could be evaluated by comparing their fracture energy, fracture strength and stress corrosion factor at the applied potentials of -1200 mV，-800 mV，-765 mV，-735 mV，-720 mV (vs. SCE). The electrolytic cell is shown in Figure 1.

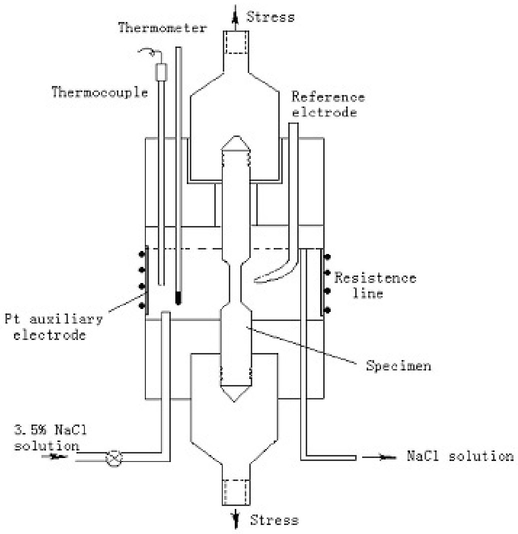


Figure 1: Electrolytic cell for SSRT tests.

The parameters used to assess the SCC susceptibility include the fracture stress σ, the fracture time t, the fracture energy E, the stress corrosion factor I_{SSRT} and the micrographic analysis of fracture surface. The stress corrosion factor I_{SSRT} is defined as one quantitative description of the SCC susceptibility after SSRT, which can reflect the stress corrosion susceptibility better than other mechanical parameters. The formula can be calculated as follow:

$$I_{SSRT} = 1 - \frac{\sigma_{fW} \times (1+\delta_{fW})}{\sigma_{fA} \times (1+\delta_{fA})} . \qquad (1)$$

In formula (1), σ_{fW} is the fracture stress in corrosion medium, σ_{fA} is the fracture stress in inert medium, δ_{fW} is the elongation in the corrosion medium, and δ_{fA} is the elongation in inert medium.

3. Results and Discussion

3.1 Effects of Polarization Potentials on SCC Behavior

In order to study the SCC behaviors of 7075-T6, 7075-T7351 and 7075-RRA aluminum alloys, the slow strain rate tension tests were performed at the free-corrosion potential and the potentials of -1200 mV SCE，-800 mV SCE，-765 mV SCE，-735 mV SCE，-720 mV SCE, respectively. The tensile curves of different tempers are shown in Figure 2, Figure 3 and Figure 4.

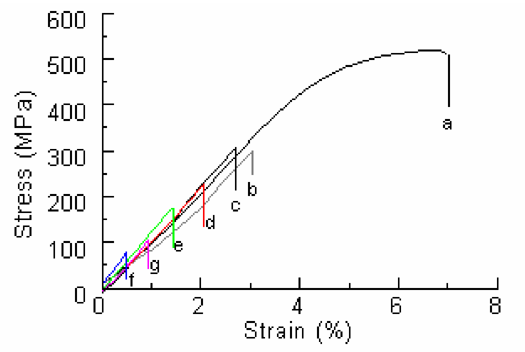


Figure 2: SSRT tensile curves for AA7075-T6 in 3.5 % NaCl solution at various applied potentials (a —in dry air, b — at open-circuit potential (-742mV SCE to -787mV SCE), c — at -1200mV SCE, d — at -800 mV SCE, e — at -765mV SCE, f—at -735mV SCE, g—at -720mV SCE).

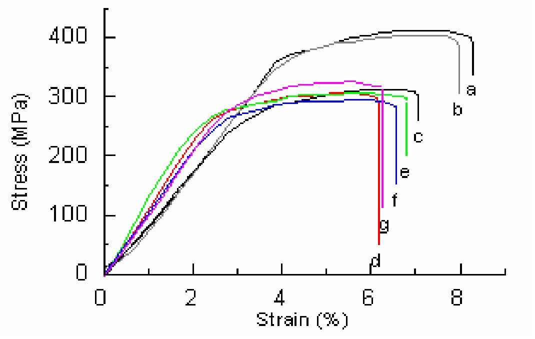


Figure 3: SSRT tensile curves for AA7075-T7351 in 3.5 % NaCl solution at various applied potentials (a —in dry air, b — at open-circuit potential (-725mV SCE to -770mV SCE), c — at -1200mV SCE, d — at -800 mV SCE, e — at -765mV SCE, f—at -735mV SCE, g—at -720mV SCE).

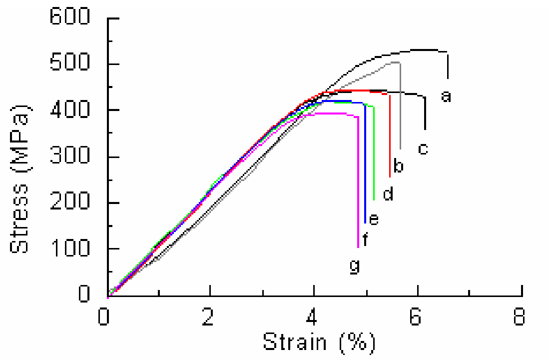


Figure 4: SSRT tensile curves for AA7075-RRA in 3.5 % NaCl solution at various applied potentials (a —in dry air, b — at open-circuit potential (-763mV SCE to -775mV SCE), c — at -1200mV SCE, d — at -800 mV SCE, e — at -765mV SCE, f—at -735mV SCE, g—at -720mV SCE).

From Figure 2 to Figure 4, it is obvious that the SCC susceptibility of AA7075 with any state is generally lower with the exception of the curve c in Figure 4 at the free-corrosion potential than that at any applied potential. This phenomenon may be due to the cathodic and anodic polarization. During the cathodic polarization at the potentials of -1200 mV SCE and -800 mV SCE, hydrogen would be generated, adsorbed and transfered into the alloy, which may facilitate the SCC susceptibility [4-7]. And the anodic dissolution would also facilitate the SCC susceptibility. The test results indicate that the cathodic and anodic polarization would be able to accelerate the stress corrosion cracking of AA7075,even though the polarization potentials are close to the free-corrosion potentials. But the degrees of acceleration for AA7075 with variant heat treatments are different. Evidently, 7075 aluminium alloy can not avoid the SCC through the cathodic and anodic polarization, at least in the range from -1200 mV to - 720 mV.

The greater the stress corrosion factor I_{SSRT} is, the higher the stress corrosion susceptibility is. The stress corrosion factors (I_{SSRT}) of all alloys are shown in Figure 5.

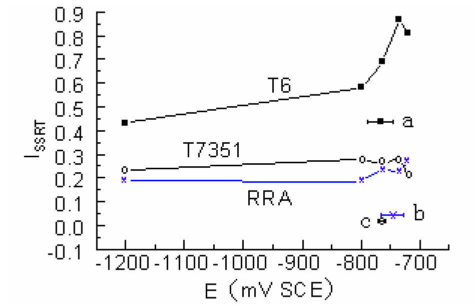


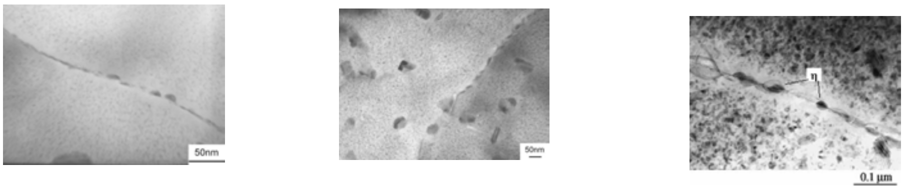
Figure 5: Stress corrosion factors I_{SSRT} of AA7075 at OCP and applied potentials (E_{corr} is the fluctuant range of free-corrosion potentials during SSRT；a — at E_{corr} of 7075-T6, b — at E_{corr} of 7075-RRA, c — at E_{corr} of 7075-T7351).

From the Figure 5, it is obvious that the stress corrosion factors (I_{SSRT}) of any tempered 7075 aluminium alloys are greater than those at the free-corrosion potentials, which agrees with the test results in Figure 2-4.

To any tempered 7075 aluminium alloy, the increased part of the stress corrosion factors caused by the cathodic polarization is generally smaller than that caused by the anodic polarization. In the cathodic polarization area, with the increase of the cathodic polarization potentials, the stress corrosion factors I_{SSRT} of T6 temper would reduce and approach to I_{SSRT} under free-corrosion potentials, but I_{SSRT} of other tempers are nearly not changed. On the other hand, in the anodic polarization area, the stress corrosion factors would increase with the anodic polarization potentials. However, when polarization potentials approach to -735 mV, the stress corrosion factors of the 7075-T6 and 7075-T7351 would reduce. Because there is no data at the potentials greater than -735 mV, it could not be confirmed whether the stress corrosion factors continue to drop or fluctuate.

The results mentioned above indicate that the cathodic polarization increases the stress corrosion factors of AA7075, which may be caused by the hydrogen effect. The level of this influence mainly depends on the susceptibility of the microscopic structure to the hydrogen effect. For the anodic polarization, the SCC susceptibility of AA7075 would be influenced both by the anodic dissolution and by the hydrogen effect at the same time. But the anodic dissolution relatively plays a more important role than the hydrogen effect. During SCC, the anodic dissolution is a very complicated process [8]. In the stress corrosion cracks, the shape of the crack tip and the anodic dissolution are the two significant factors influencing the SCC susceptibility. The anodic dissolution could promote the propagation of the stress corrosion cracks, but severe anodic dissolution could make the crack tip blunt. Stress concentration is very difficult to develop in these blunt tips, which would slow down and even stop the propagation of the stress corrosion cracks. Therefore, the stress corrosion factors of AA7075 would not drastically increase with the anodic polarization potentials.

The influences of both anodic and cathodic polarization on SCC susceptibilities are closely related to the microstructures of the alloys, such as the continuity of the grain boundary precipitates and the width of the precipitate free zones (PFZ). Figure 6 shows that 7075-T6 has more continuous grain boundary precipitates and narrower precipitate free zones (PFZ) than T7 or RRA tempered alloys, which might account for the low SCC resistance of AA7075 with T6 temper.



7075T6 7075 RRA 7075 T7

Figure 6: The TEM microphotograph of the microstructure of the 7075-T6[9], RRA[9] and T7 [10]．

From the analysis mentioned above, it is summarized that the stress corrosion susceptibility of 7075 aluminium alloy would increase at the applied potentials, even at the weak polarization potentials. So it is dangerous to avoid the stress corrosion through the electrochemical protection method. In order to protect 7075 aluminium alloy, it would be reasonable to develop new corrosion inhibitor.

4. Conclusions

1. The 7075-T6 aluminium alloy is susceptible to the stress corrosion cracking on account of the anodic dissolution reaction or the cathodic hydrogen reaction on the alloy surface, even at the weak applied potentials.
2. That the SCC susceptibility increases with both the anodic and cathodic polarization potential indicates that the anodic dissolution and hydrogen mechanisms influence the propagation of the stress corrosion cracks during SCC.
3. The stress corrosion susceptibility of 7075 aluminium alloys with different heat treatments are different because of the difference of microscopic structures.

Acknowledgments

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