# Study on Initiation and Growth of Fatigue Crack of Pre-corroded 7B04 Aluminium Alloy Specimen

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**Abstract**. The purpose is to study the fatigue crack initiation and propagation behavior of aluminum alloy under pre corrosive damage. The high strength aluminum alloy 7B04-T74 with main bearing structure of aircraft was used to prepare single edge notched specimens for pre corrosion and fatigue tests, and the effects of corrosion damage on fatigue crack initiation and propagation are analyzed. It is found that the fatigue crack sprout at the bottom of a single corrosion pit at a low corrosion period, and the length of the crack is equivalent to the width of the corrosion pit, about 0.047mm, and the crack propagates in a straight line. At high corrosion stage, cracks occur at multiple corrosion pits, and the crack propagation paths become tortuous, resulting in glyph cracks.

## 1. Introduction

During the service of the aircraft, the corrosion damage caused by the comprehensive factors such as the environment and the fatigue load generated during the flight are the two main causes of the failure of the relevant structural performance [1, 2]. Aircraft operating in severe and complex environments tend to corrode aluminum alloy structures, resulting in a decay in service life and a potential threat to flight safety.

The impact of corrosion on the fatigue performance of aircraft structures has been highly valued by countries around the world, and many studies have been carried out at home and abroad. Zhou Song et al [3] studied the fatigue properties and fracture mechanism of aerospace aluminium alloy under pre-corrosion. The results show that the corrosion pre-damage has a significant effect on the fatigue life of 7075 aluminium alloy material. After 24 hours of pre-corrosion, the median fatigue life of the samples decreased by 31.74% and 26.92% compared with the uncorroded samples. Liu Jianzhong [4] studied the fatigue fracture behaviour of corrosion-resistant pre-damaged aluminium alloy 2024-T62 by coating method. The results show that the corrosion pre-damage has a significant effect on the material fatigue SN curve and the material fatigue small crack initiation behaviour, but there is no obvious influence on the long and short crack propagation of the material and the physical small crack threshold value expansion behavior. The above research has achieved a lot of results. From the current research status, there are still some shortcomings. First, when conducting corrosion tests, it is mainly based on existing relevant standards and does not fully comply with the actual service conditions of the aircraft; second, the study on the impact of corrosion damage on fatigue performance does not distinguish between crack initiation and crack propagation.

In this paper, the effects of different degrees of corrosion damage on the fatigue crack initiation and propagation behavior of 7B04 aluminium alloy materials were studied for the 7B04 aluminium alloy materials by accelerated corrosion test under simulated service conditions, which is of great significance for ensuring the safe service of the aircraft.

## 2. Test

### *2.1. Test piece*
The test piece material is made of high-strength aluminum alloy 7B04-T74 with main bearing structure of the aircraft. The test piece is Single Edge Notch Tension (SENT). The notch is semi-circular and the thickness is 5mm. Other dimensions are shown in Figure 1.

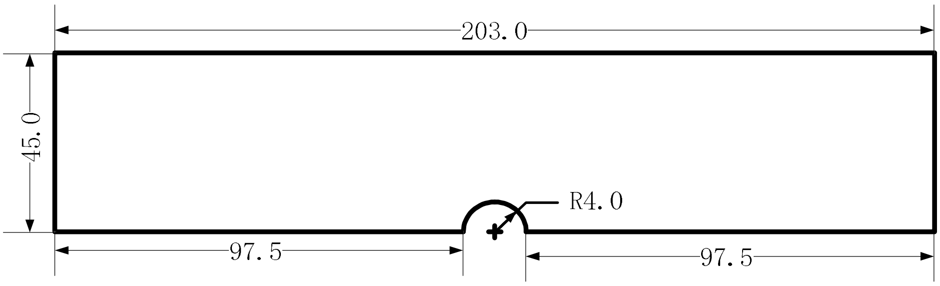



**Figure 1.** Single-edge-notch specimen

### *2.2. Accelerated corrosion test*
Simulate the aircraft's outfield service environment and conduct accelerated corrosion tests. The method for accelerating the etching solution is as follows: ① using 95 parts of distilled water and 5 parts of NaCl having a purity of 99.9% to prepare a NaCl solution having a concentration of 5%; ② adding an appropriate amount of dilute sulfuric acid to make the pH of the NaCl solution 4.0±0.2. Before the corrosion test, the parts other than the notch of the test piece are protected with anti-corrosion sealant to remove the influence of other factors on the fatigue crack initiation and expansion behavior. The ZJF-75G periodic infiltration test chamber was used to carry out the equivalent accelerated corrosion test for 0 years to 12 years. The test pieces were divided into 4 groups, and the corresponding corrosion time was 3 years, 6 years, 9 years and 12 years, namely 3a, 6a, 9a, 12a, the number of test pieces in each group is 6. Figure 2 shows the accelerated corrosion test state of the test piece.

**Figure 2.** Accelerated corrosion test state of specimens

### *2.3. Fatigue test*
The test piece of the accelerated corrosion 0a, 3a, 6a, 9a, 12a was subjected to a fatigue test using an electro-hydraulic servo fatigue tester Material Test System 810. According to HB 7705-2001 "Test method for fatigue crack growth rate of metallic materials" [7], the metallographic AC paper replica was used to monitor the fatigue crack initiation and expansion at the notch of the test piece. The stress ratio

is R=0.06, the maximum stress $\sigma_{max}$=98 MPa, the loading frequency $f$=10 Hz, and the constant amplitude loading mode is shown in Figure 3.

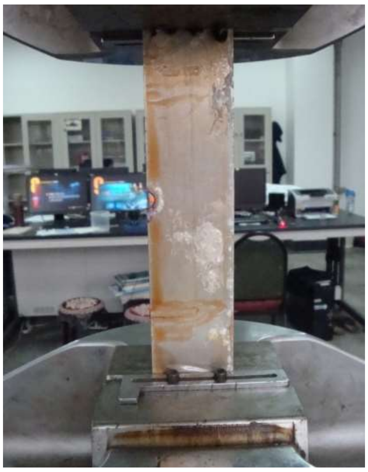
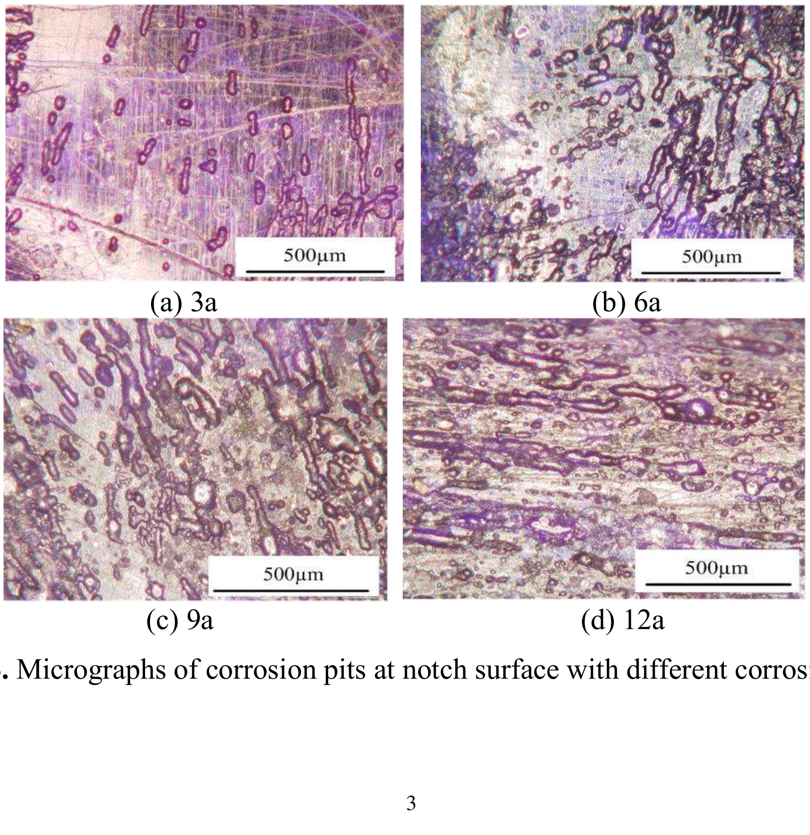


**Figure 3.** Replicas of specimen

## 3. Results and discussion

### *3.1. Corrosion morphology under different corrosion years*

Figure 4 shows the distribution and morphology of the corrosion pits on the semi-circular notch surface of the specimens with equivalent corrosion years 3a, 6a, 9a and 12a under optical microscope. When the equivalent corrosion is 3a, the number of corrosion pits on the surface of the semi-circular notch is less and more dispersed, and the size of the corrosion pit is smaller and independent of each other; when the equivalent corrosion is 6a, the multiple corrosion pits are connected to each other; after the equivalent corrosion of 9a, the corrosion pit has become more and more In saturation, it is spread over the entire surface of the notch, and the corrosion pit connection is intensified, forming a large area of corrosion.




(a) 3a (b) 6a

(c) 9a (d) 12a

**Figure 4.** Micrographs of corrosion pits at notch surface with different corrosion years

### *3.2. Fatigue crack initiation and expansion behavior*

Figures 5 and 6 clearly show the process of cracking, expanding and extending of the surface crack of 7B04 aluminum alloy from the corrosion pit. The crack is initiated from the bottom of the etch pit 1 between 10, 000 and 15,000 cycles. The crack length is equivalent to the width of the etch pit, which is about 0.047 mm. As shown in Fig. 5 (a), for the 7B04 aluminum alloy material under pre-corrosion damage, The crack usually originates from the pit, which is confirmed in the SEM micrographs in Fig. 7(c) and Fig. 7 (d); after the fatigue loading is continued, the crack at the etch pit expands, as shown in Fig. 5 (b)~5 (d); when loaded to 52000cycles, the crack propagates to 2.93mm and a second crack is produced, as shown in Figure 5 (e); at 54000cycles, the two cracks begin to meet and form a main crack. As shown in Figure 5 (f).

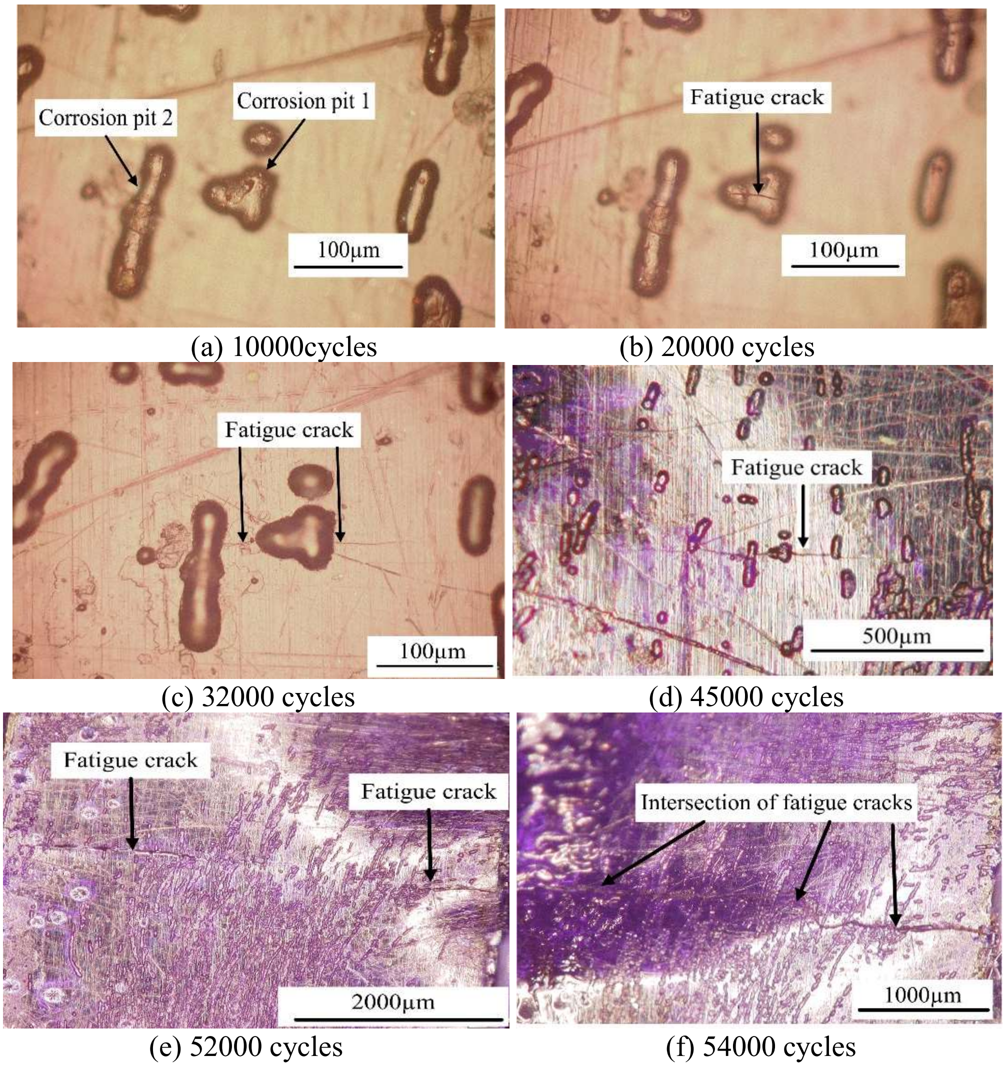



**Figure 5.** Micrographs of surface replicas showing initiation site and crack-growth

For uncorroded test pieces, the fatigue cracks extend substantially linearly, as shown in Fig. 6(a). For the corrosion specimens 3a and 6a, the crack propagation is affected by corrosion damage due to the early and intermediate stages of corrosion. The crack propagation path is still relatively flat and the fluctuation is not large, as shown in Figures 6 (b) and 6 (c). As the corrosion age increases, the corrosion of the notched surface of the test piece is intensified, and the number of corrosion pits is increased. Increasingly, and from a single corrosion pit to multiple corrosion pits connected to each other, forming a large area of corrosion damage, as shown in Figure 6 (d); under fatigue loading, due to large area of corrosion damage to form local stress concentration [8] -10], promotes the expansion of fatigue cracks, and causes the crack propagation path to be tortuous, resulting in a zigzag deflection, as shown in Figures 6 (e) and 6 (f).

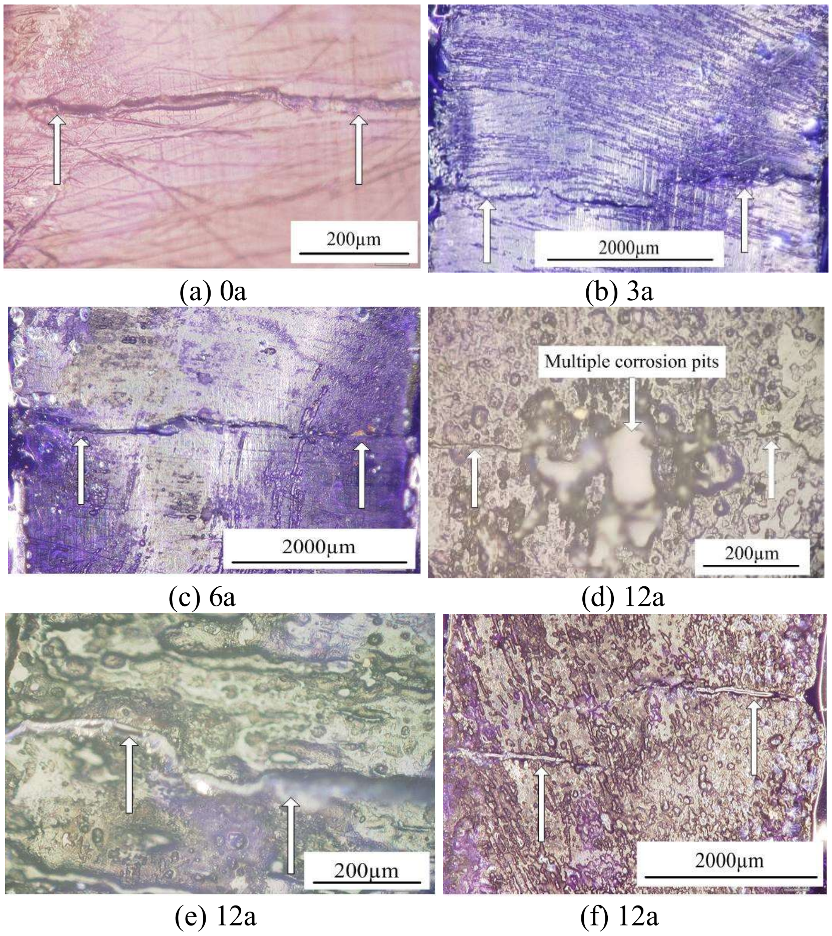



**Figure 6.** Micrographs of crack-growth path

## 4. Conclusion

(1) When the equivalent corrosion is 3a, the number of corrosion pits on the surface of the semi-circular notch is less and more dispersed, and the size of the corrosion pit is smaller and independent of each other; when the equivalent corrosion is 6a, the multiple corrosion pits are connected to each other; after the equivalent corrosion of 9a, the corrosion pit has become more and more In saturation, it is spread over the entire surface of the notch, and the corrosion pit connection is intensified, forming a large area of corrosion.

(2) At a lower corrosion age, the fatigue cracks extend substantially in a straight line. As the age of corrosion increases, the expansion of the crack becomes tortuous, and a "Z" path appears.

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