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Fatigue Behavior and Uniformly Distributed Cracks of Electrodeposited Iron

電着鉄の疲れ挙動と分布き裂

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1. Introduction

The authors investigated the fatigue behavior and uniformly distributed cracks on fatigued copper films electrodeposited on ABS plastics[1], and found that the method is very useful for investigating the mechanisms of initiation and growth of cracks. In this work, electrodeposited iron films were used for fatigue specimen, and difference in behavior of these two metals was investigated.

2. Fatigue tests

(1) Fatigue tests

Both repeated bending and repeated torsion tests were performed on specimens as reported in the previous experiments.

(2) Electrodeposition of iron

Electrolyte used for electrodeposition of iron was Fischer – Langbeim solution as indicated below:

$FeCl_2 \cdot 4H_2O$: 300 g/l, $CaCl_2$: 335g/l

Depositing conditions were;

Temperature of the bath: 90 °C, pH: 0. 8 ～ 1. 5

Current density: 6. 5 A/dm^2, Mechanical stirring.

Since the deposition is performed at high temperature, the ferrous ions are easily oxidized to ferric ones, and the deposition was apt to be fragile. However, the electrolyte was used, because the grain size of the deposition was fine and the surface was lustrous. It was very difficult to have electroless deposition of iron, directly on plastics. The electroless copper and copper strike were used for initial conducting film. The thickness of copper and iron was about 2 ～ 3 μm and 20 μm, respectively.

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3. Experimental results

(1) Tensile test

A stress – strain curve for the electrodeposited iron was similar to that of mild steel. The result is indicated in Table 1. The tensile stress value was about 40 kg/mm^2. The value of Young's modulus was scattered in each experiment and could not be determined.

Table 1　Tensile test results

Specimen No	1	2	3	4
Young's modulus, kg/mm²	4.1×10^4	2.3×10^4	1.4×10^4	5.3×10^3
Tensile strength, kg/mm²	39.4	42.6	41.8	28.3

(2) Fatigue test, S–N curve

A S–N curve for the repeated bending test is shown in Fig. 1. In comparing the result with that

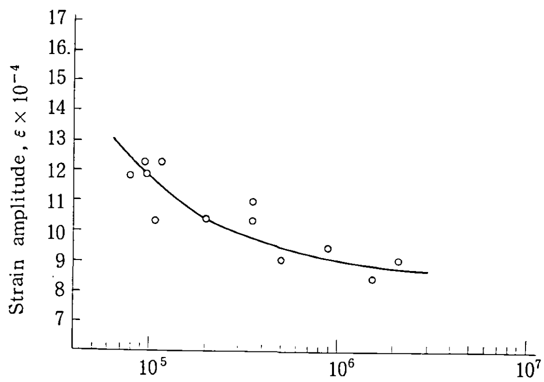

Fig. 1　A S–N curve for ABS plastics plated with iron

of copper, the fatigue strength of electrodeposited iron was lower than that of copper in higher strain amplitude and was higher than that of copper in lower strain amplitude. Both S–N curves crosses at about N = 10^6. The reason was not clear, but an observable result that the occurrence of cracks was fewer in iron film at lower strain amplitude would contribute the high fatigue strength.

(3) Uniformly distributed cracks

Cracks on iron film were initiated from slips in crystals, and uniformly distributed minute cracks were observed on whole surface of specimens. In the morphological point of view, these were shorter and broader than these on copper. Fig. 2 shows uniformly distributed cracks by the repeated bending test and these are oriented on direction of the maximum shearing stress, i. e. 45° to the stress axis.

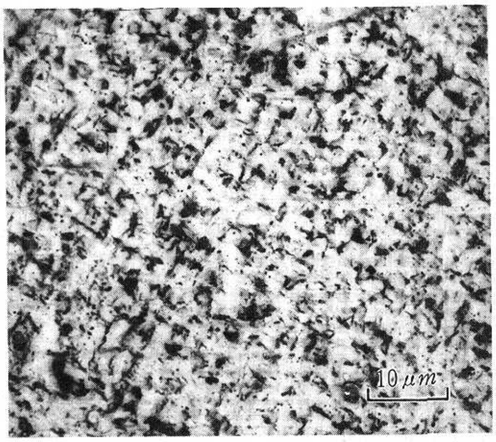

Fig. 2 Uniformly distributed cracks on iron film by repeated bending test ($\varepsilon = 1.18\times10^{-3}$, $N = 6.86\times10^{4}$)

Fig. 3a shows uniformly distributed cracks by repeated torsion test and these are oriented on both parallel and vertical direction of the specimen axis. Length of the cracks were usually several micron, and few cracks were longer than 10 μm. Fig. 3b shows an electron micrograph of the cracks formed on the same specimen.

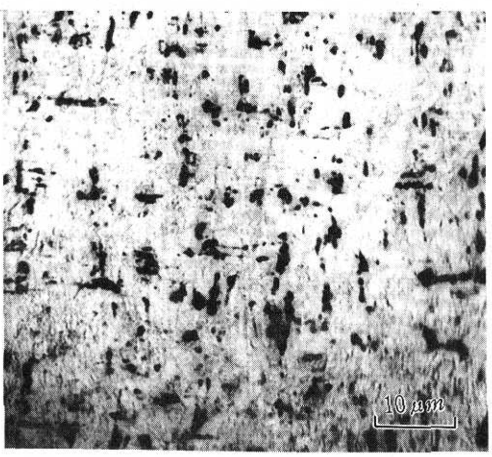

Fig. 3a Uniformly distributed cracks on iron film by repeated torsion test

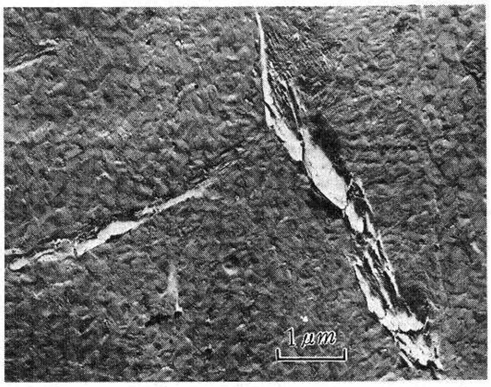

Fig. 3b Electron-micrograph of lhe cracks occurred at perpendicular direction

Branching of cracks sometimes occurred. Fig. 4 shows branching of a main crack. The angle between these branches was different from that of copper, and many small cracks with various cross angles were observable.

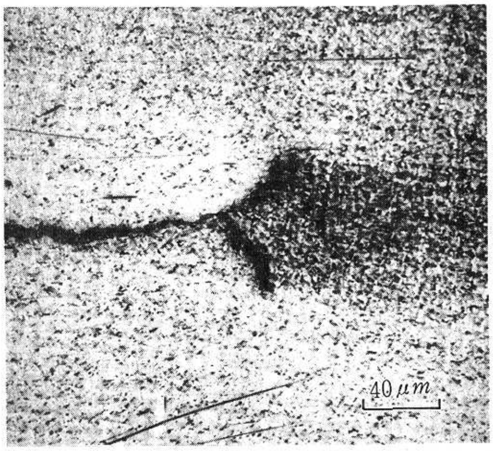

Fig. 4 Branching of a main crack

The transition of these cracks to rupture occurred by connection of the cracks and/or formation of a main crack. Rupture connecting the main cracks frequently appeared in large strain amplitude region in S−N curve, and from a defect on the surface. Therefore, rupture through the uniformly distributed cracks ocurred in small strain amplitude region and on a good surface. Fig. 5 shows an example in a repeated bending specimen.

Number of uniformly distributed cracks in fatigue test could be counted in the experiment as in the case of copper. In this experiment, the number of cracks was counted in the strain amplitude of

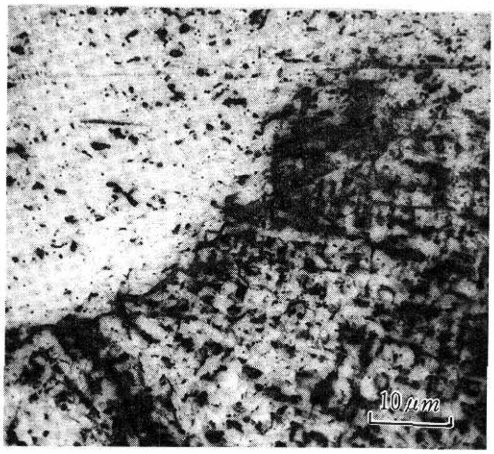

Fig. 5 Rupture by connecting the uniformly distributed cracks in a repeated bending specimen

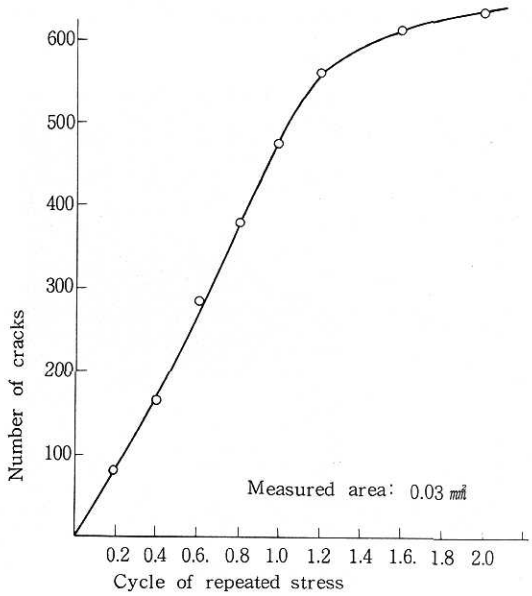

Fig. 6. Initiation process of the uniformly distributed cracks on iron

1.5×10^{-3}, at every stress repetition of 0.2×10^{-5} to 2.0×10^{-5}, and in an area of 0.03mm². Fig. 6 shows the result and similar to the experiment in copper.[2] Saturated number is 633 at the repetition of 2.0×10^{-5}. This is 17 times more than that of copper in unit area. This indicated that more dislocations that grew to slip cracks appeared and that the dislocation density of this material was denser than that of copper.

4. Discussions

It was found that the fatigue cracks on iron surface electrodeposited on ABS plastics could be discussed by the same criteria as that of copper. At first, the uniformly distributed cracks corresponding to stage I appeared. The cracks which led to rupture were originated from connecting the uniformly distributed cracks in a small strain amplitude region and on a surface with less defects.

In order to investigate the mechanism of crack formation in electrodeposited iron, slip mechanism in a single crystal would be necessary. By the replica method in electron microscopy, the slip in a grain could not be clarifjed. It was very difficult for the authors to make simgle crystal iron film, because a large single crystal was necessary for the purpose.

Literature

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