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# Microstructure Analysis for the Ultrasonic Fatigued Alloys using SANS

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## 1. Introduction

The ultrasonic fatigue test has big benefit on the evaluation of the materials life by reducing the testing time from a few years (in the case of standard fatigue testing equipment; ~ 200 cycles/s) to a few days. For this reason, several researchers have been used this testing method for their study on the mechanism of the crack initiation and fracture cause by the fatigue [1-5].

In this study, the variation of the microstructure owing to the fatigue test for some aluminum alloys and Cu-Zn alloys was investigated. Several aluminum and Cu-Zn alloy samples were prepared by ultrasonic fatigue as a function of testing time. Small angle neutron scattering (SANS) measurement was performed to investigate a signature from the nanosize pores or cracks, etc., in the sample matrix. Also, TEM work was carried out.

## 2. Experimental

For the fatigue samples, commercial Al6061, Al1050 and Cu-Zn alloy were used. The fatigue test was performed by using ultrasonic fatigue test equipment; the load of fatigue test is controlled by displacement (10~55 μm) and frequency is 20 KHz. For the SANS measurement, fatigue tested samples were cut as 1 mm thickness at the center of the each test sample.

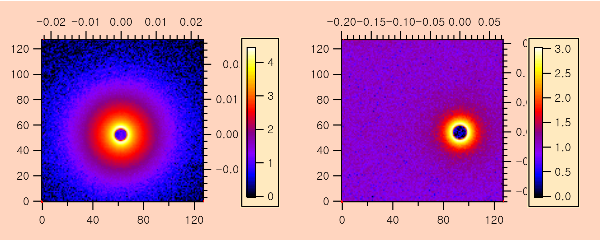
SANS measurement was performed at 18M-SANS (HANARO, KAERI). The used neutron wavelengths were 0.95 nm for 9 m and 0.48 nm for 3 m. TEM images for several samples were taken to observe the microstructure.

## 3. Results

### 3.1 Al 6061

Fig. 1 shows 2D SANS patterns of Al6061 as an example. Each sample was measured at two SANS set-ups; 0.95 nm for 9 m and 0.48nm for 3 m. The 1D SANS pattern was obtained by azimuthal averaging from 2D SANS patterns. Fig. 2 shows the 1D SANS patterns for Al6061 samples. The SANS patterns showed clear difference in intensity. Especially, the sample tested for 5 minutes showed the highest increasing rate. After that, the scattering intensities gradually increased as increasing testing time. Only a small bump is shown in the Q-range of $0.004 < Q < 0.008$(/Å).

In Fig. 3, TEM images of 5 min, 30 min samples were presented. In the 5 min sample, some small precipitates and few dislocations were observed. On the other hand, in the 30 min sample, lots of dislocations and precipitates were observed.



(a) Low Q : 9m (b) High Q : 3m

Fig. 1. 2D SANS patterns of Al6061

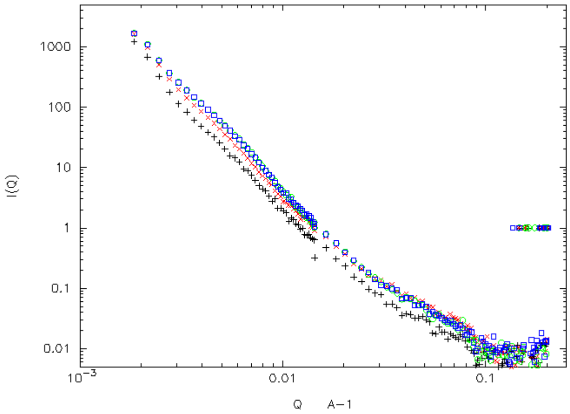
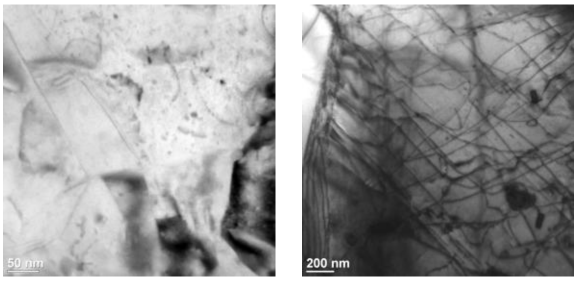


Fig. 2. 1D SANS patterns of Al 6061; + 0 min, × 5 min, ○ 10 min and □ 30 min.



(a) 5 min (b) 30 min

Fig. 3. TEM images of Al 6061

### 3.2 Al 1050

In Fig. 4, the 1D SANS patterns of Al1050 were presented. As shown in figures, there isn't any difference according to the fatigue testing time. Even if when the testing time increased up to10 hours(~8 x$10^8$ cycle) and the displacement was varied from 17 to 23 μm, there is no difference in SANS pattern. As shown in Fig. 5, the TEM image of 32 min sample shows very clean matrix.

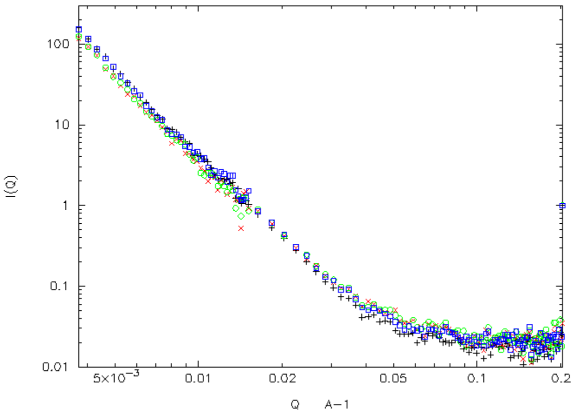


Fig. 4. 1D SANS pattern of Al 1050; + 0 min, × 1 min, ○ 5 min and □ 32 min.

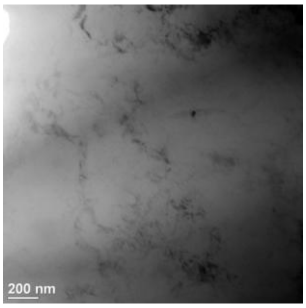


Fig. 5. TEM image of Al 1050: 32 min sample

### 3.3 Cu-Zn alloy

As shown in Fig. 6, the SANS patterns of Cu-Zn alloys were varied with fatigue test cycle. The variation is clear in the middle Q-range of $0.004 < Q < 0.02$(/Å). The peak position of small bump of SANS pattern for each sample moved to lower Q region as increase the testing cycle.

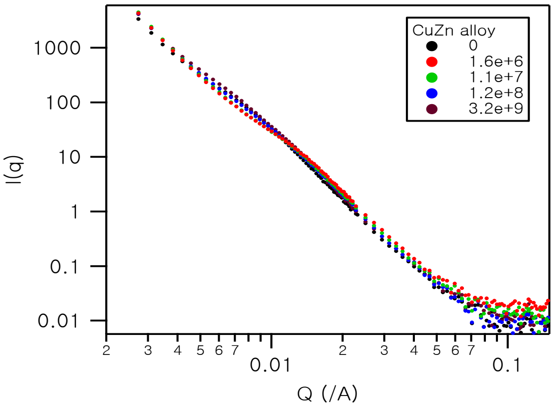


Fig. 6. 1D SANS pattern of Cu-Zn alloys

However, any particular image, such as precipitate, dislocation, fine crack, etc., wasn't observed in the TEM measurement.

## 4. **Conclusion**

In the case of Al6061 as an alloy sample with a lot of precipitates, the microstructure seems to be varied mostly in the initial stage of ultrasonic fatigue test (in 5 min) then varied slightly as increase the fatigue testing time. The inhomogeneity that make the SANS pattern seems to be more than two kind; one can be the dislocations occurred during fatigue test, and the other is can be the several kinds of precipitates in the aluminum matrix. The fine precipitates maybe can grow a little cause by the heat isolated inside the sample during the fatigue test.

In the case of Al1050, the sample is nearly pure aluminum with clean matrix and good ductility. So any variation of the microstructure was not observed in the ultrasonic fatigue test, so that make no difference in SANS pattern.

Cu-Zn alloy is two phase alloy with α-brass(fcc) and β-brass(bcc). Some study for two phase alloy showed a sub-crack in the interface of phases after fatigue test[1]. So we can carefully image very fine sub-cracks or pores in the interface of α-brass and β-brass, it maybe can make SANS patterns but hard to be observed in TEM.

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