ACOUSTIC EMISSION OF FATIGUE-DEFORMED ALUMMINUM ALLOYS FOR AUTOMOTIVE PANELS

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ABSTRACT

Acoustic emission behavior during fatigue deformation and fracture was investigated in Al-Mg-Si alloys for automotive body panels. Generation of fatigue cracks was clearly identified by the burst of AE signals at the early stage of fatigue test. During the middle stage of fatigue, AE signals having low amplitude about 60dB corresponding to the propagation of striations appeared continuously. At the moment of fracture, AE with amplitude ranging from 50 to 80 dB was detected by the microscopic changes from striations to transgranular voids.

Keywords; Acoustic emission, Fatigue, Al-Mg-Si alloy, T4 treatment, Fracture

INTRODUCTION

Much attention has been paid to reduce the emission of carbon dioxide to the global atmosphere by reducing the weight of automobile. For this purpose, metallic materials for car body panels have been replaced from the iron-based metals to the aluminum-based ones. Among the industrial aluminum alloys, Al-Mg-Si based ones (6000 series) has been widely used for car body panels because they shows better formability, weldability, and corrosion resistance with an intermediate strength. For automotive use, the Al-Mg-Si alloys are formed in the naturally aged condition after the solution heat treatment, and then bake-hardened around 180˚C when painting [1-3]. Since the application of Al-Mg-Si alloys for car body panels is now in under progress, fatigue properties of Al-Mg-Si alloys have not been fully understood. In this study, acoustic emission during fatigue test was examined for the Al-Mg-Si alloys to detect the initiation and propagation of fatigue cracks

EXPERIMENTAL

Two kinds of Al-Mg-Si base alloys, in which the silicon content was different, were supplied from the manufacturer. Chemical composition of the alloys was shown in Table 1. All alloy ingots were homogenized and warm and cold rolled to the thickness of 1mm. Test specimens having a gage length of 20mm, width of 5mm and thickness of 1mm were cut from the rolling sheets using an electro-dispersive machining. In order to fix the position of initial fatigue crack, notched specimens were used. The notch plane was perpendicular to the rolling direction. Curvature of the notch front was 100μm and the stress intensity factor was calculated to be 4.5. Test specimens were solution heat treated at 510˚C for 1 h and then quenched in water. After the solution heat treatment, the specimens were naturally aged for 1 week (T4) and artificially aged at 175˚C for 0.5h (BH). Fatigue tests of notched specimens are carried out using a servo-hydraulic testing machine (EFH-100) at a frequency of 15Hz and stress ratio R=0, with a sinusoidal waveform. Crack length was measured on one specimen side with a CCD microscope. Surface of the test specimen was observed with a scanning electron microscope (Hitachi, S-4700). Before testing, two AE sensors with 200kHz resonant frequency were attached at the gage parts of the test specimen, respectively. AE signals converted into electrical signals were amplified by a total gain of 60dB using an amplifier and passed through a band pass filter with the range from 100 to 1200 kHz. Threshold level of AE amplitude was 60 and the time interval between the two sensors was within 10 μs to detect AE in only the deformed region. Obtained AE signals having frequency ranges between 0.1~1.2 MHz were analyzed with a computer system (Mistras 2001, PAC).

Table 1 Chemical composition of Al-Mg-Si alloys [wt.%]

Alloy	Mg	Si	Cu	Fe	Mn	Zn	Al
#1	0.70	0.46	0.34	0.03	<0.01	<0.01	Bal.
#2	0.70	0.76	0.34	0.03	<0.01	<0.01	Bal.

RESULTS AND DISCUSSION

Fatigue life for T4 and BH specimens was plotted as a function of maximum cyclic stress as shown in Fig.1. The fatigue strength defined as the maximum cyclic stresses corresponding to the fatigue life of 1x10^7 cycles were increased by 30% when the Al-Mg-Si alloy containing excess silicon was aged at 175˚C for 0.5h. Figure 2 shows the relationship between AE amplitude and the number of cycles tested on stress amplitude of 61dB in T4 specimens. No clear AE signals were observed at a comparably early stage of fatigue test. This represents that all electrical noises caused

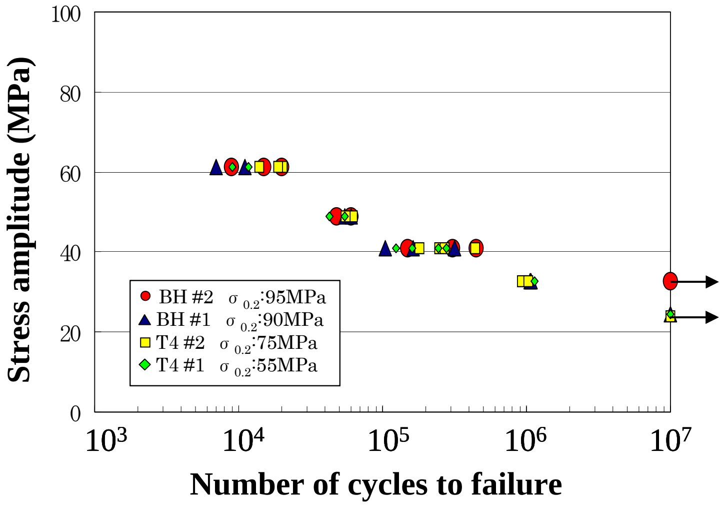

Fig.1 Stress amplitude vs. number of cycles to failure

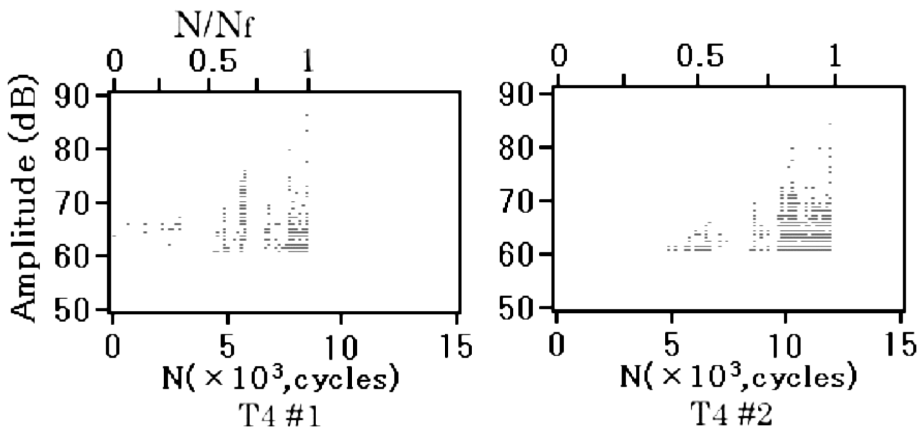

Fig.2 Relationship between AE amplitude and number of cycles of T4 #1 and T4 #2. (Stress amplitude:61MPa)

by the vibration of testing machine was removed when the threshold of 60dB was set. In both specimens with and without silicon, burst of AE signals was firstly appeared around the cycles N/N_f=0.25, probably due to the initiation of fatigue cracks. It was assumed that additional excess silicon retarded the initiation of fatigue cracks. On the other hand, the frequency of AE bursts having a wide amplitude range increased with

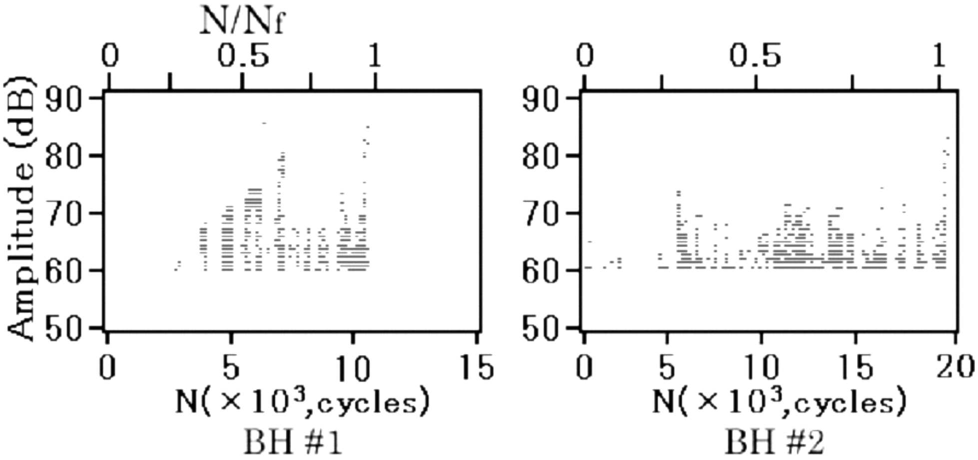

Fig.3 Relationship between AE amplitude and number of cycles of BH #1 and BH #2.
(Stress amplitude:61MPa)

increasing the cycles at a late stage of fatigue cycles around N/N_f=0.75. At the moment of fracture, AE, which was associated with the propagation of fatigue cracks having high amplitude ranges (80dB), was also detected. Figure 3 shows the variation of AE amplitude during the fatigue test in BH specimens. In the similar way as T4 specimens, AE bursts were observed around the cycles N/N_f=0.25, while no AE signals were visible at the beginning of the fatigue test. Fracture surfaces showed that reduction in area was decreased as approached to the notch point as shown in Fig.4. There was no difference in macroscopic morphology in T4 and BH specimens fractured on stress amplitude of 61dB. Magnified image as shown in Fig.5 revealed that the fracture surfaces near the notch point were covered with flat planes in which AE signals were detected at the fatigue cycles N/N_f=0.25. In addition to this, a number of etch pits with a shape of triangle representing a slip plane of aluminum {111} were visible on the flat plane. Thus, it is noted that the fatigue crack was generated by the separation of slip planes.

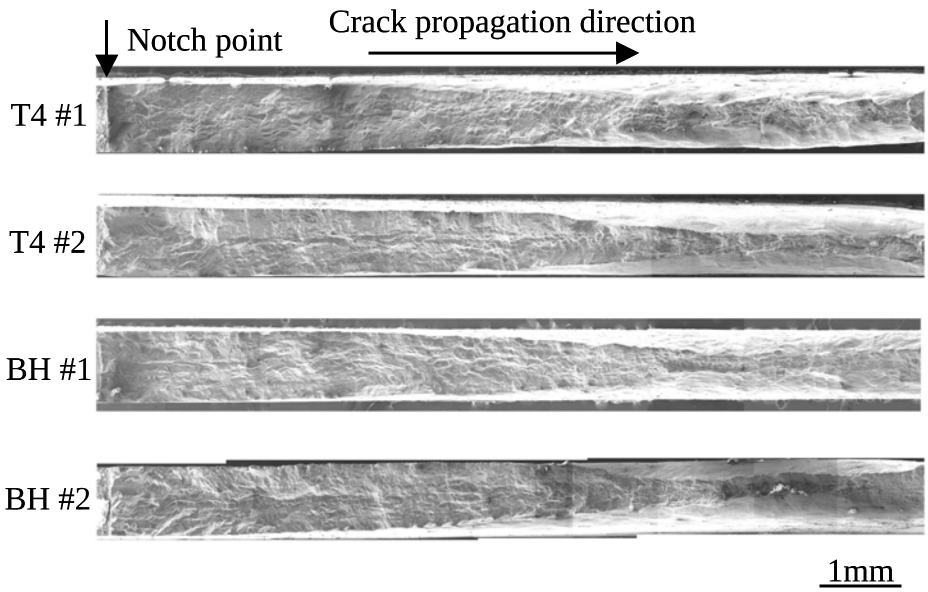

Fig. 4 Morphology of the fracture surfaces.

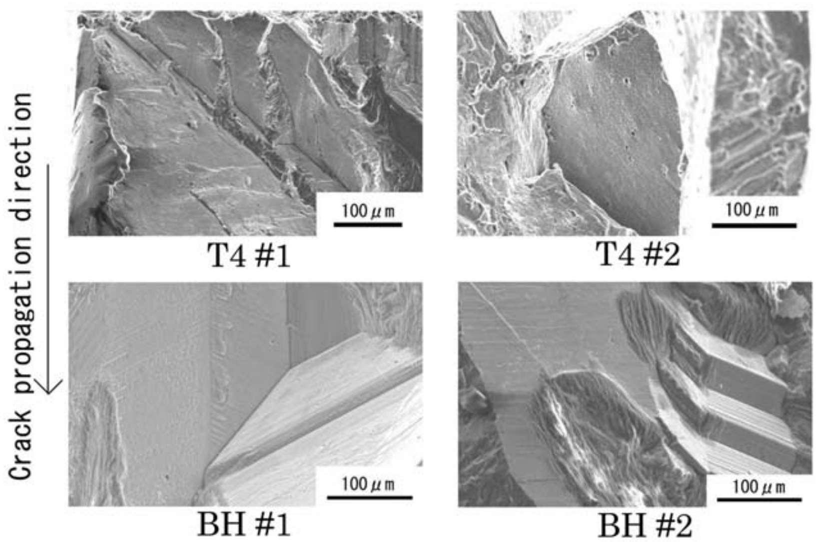

Fig. 5 Fracture surfaces near the notch point.

Fracture surfaces being 3mm apart in direction from the notch point showed that arrangement of the striation was observed in all the specimens as shown in Fig.6. The width of the striations of T4 specimens was narrower than that of BH specimens. The narrow width of the striation corresponded to the retardation of the crack propagation leading to a long fatigue life in BH specimens.

Fracture surfaces opposite side from the notch point as indicated in Fig. 7 showed that the fracture morphology was changed from striations to transgranular voids. The transgranular void in the specimens with excess silicon (T4#2, BH#2) was shallower than that without excess silicon (T4#1, BH#1). This result was in accordance with the previous results obtained by the tensile test [4] that the AE amplitude observed at the moment of fracture was related to the morphology of transgranular voids.

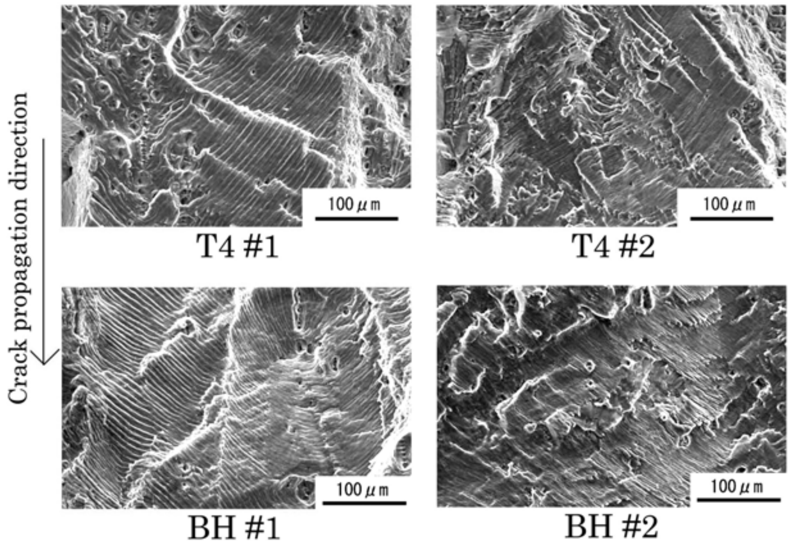

Fig.6 Fracture surfaces being 3mm in apart from the notch point.

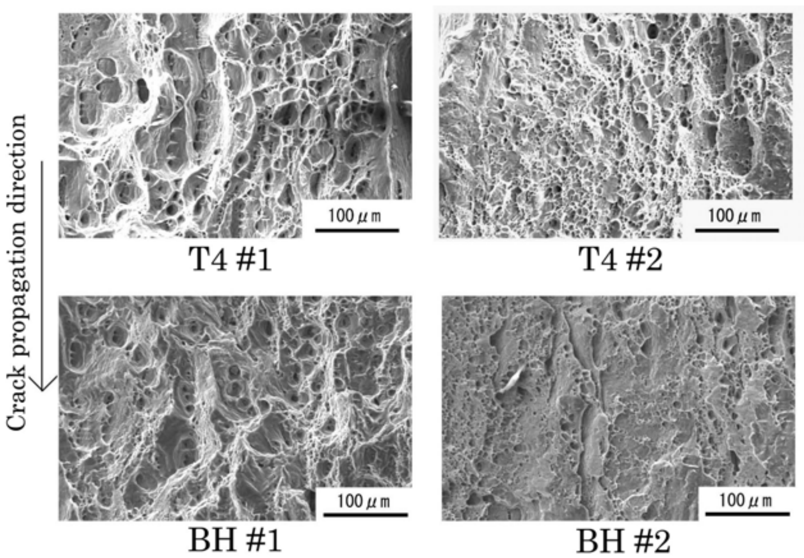

Fig.7 Fracture surfaces near the final fracture point.

CONCLUSIONS

(1) Fatigue strength was increased by 30% when the Al-Mg-Si specimen containing excess silicon was aged at 175˚C for 0.5h.
(2) Generation of fatigue cracks was clearly identified by the AE signal with an amplitude about 60dB at the fatigue cycles N/N_f=0.25.
(3) Variation in AE amplitude appeared at the fatigue cycles N/N_f=0.5 corresponds to the formation of striations during the crack propagation.
(4). At the moment of fatigue fracture, AE signals with high amplitudes (80dB) were detected accompanied by the changing of fracture morphology from striations to transgranular voids.

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