DEVELOPMENT OF NON-CONTACT FATIGUE CRACK PROPAGATION MONITORING METHOD USING AIR-COUPLED ACOUSTIC EMISSION SYSTEM

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1. Introduction

The acoustic emission (AE) method is the efficient monitoring technique, and it can be used to assess the integrity of the equipment during operation. Especially, AE method enables to observed fatigue crack propagation by investigating the AE analysis and predicts fatigue life [1]. However, the fatigue monitoring of rotating components during operation is difficult because attaching the sensor to the surface of the rotating component is difficult. In order to overcome this problem, a non-contact AE monitoring system was developed and used for the fatigue monitoring of rotating components [2]. Even though, the AE signals were detected immediately before fracture, the AE signals from crack initiation and propagation at an early stage were not detected. The purpose of this study is to develop the method for fatigue crack monitoring of AE. We first clarified the relationship between sensor sensitivity and surface condition of the specimen. Next, AE signals from bending fatigue test in rotating component was monitored using modified specimen.

2. Relationship between surface condition of the specimen and sensitivity of the system

The relationship between the sensitivity of the AE signals detected by the system and the configuration of the specimen during the test was first investigated. The amplitude of the artificial AE signals propagated in the arc and flat surface specimen were compared. The arc surface specimen was a rod of diameter 18 mm. The flat surface specimen was machined by milling a cylinder of diameter 18 mm on the upper side at a depth of 4 mm and length of 25 mm. The air coupled ultrasonic sensor for detecting AE signal was set over the surface at a distance of 20 mm. The artificial AE was generated by a pulse YAG laser at 8.0 mJ on the end surface of the specimen. Figure 1 shows the waveforms generated by the pulse YAG laser on (a) the arc specimen and the (b) flat surface. The SN ratio of the signals in the arc and the flat surface were 26.3 dB and 38.4 dB, respectively. This result indicated that the SN ratio of AE signals was dependent on the configuration of the specimen. It was necessary to consider the configuration of the specimen used in the rotary bending fatigue test to detect the AE signals at an early stage.

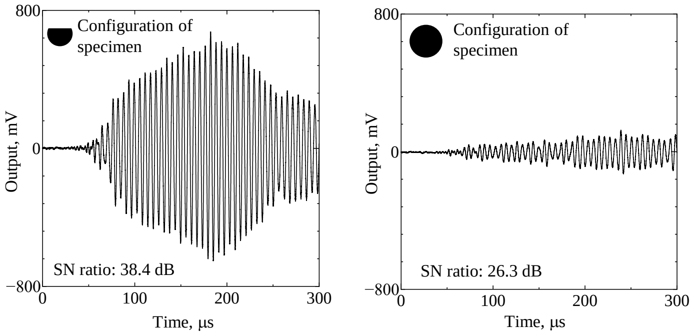

Figure 1: Waveforms detected by air-coupled ultrasonic sensor in arc (left) and flat (right) surface specimen.

3. AE monitoring during the rotary bending fatigue test using the circular bar specimen with flat surfaces

The result in Fig.1 indicated that the plane surface shape was higher efficiency than the arc surface shape using the air-coupled ultrasonic sensor. Therefore, the circular bar specimen with flat surface for rotary bending fatigue test was machined and utilized for fatigue monitoring. Figure 2 shows the specimen configuration and experimental setup. The specimen was an aluminum alloy (A2024) with 18 mm diameter and 120 mm length. The flat surface was made by milling a cylinder of diameter 18 mm on the upper and under side at a depth of 4 mm and length of 25 mm. The slit with 0.5 mm depth and 1 mm width was made on the end of the flat surface in order to limit the locations of crack initiation. This specimen was mirror finished surface because it was easy to observe the fatigue cracks. The fatigue crack length on the surface of this specimen measured by the replica method. The loading frequency was 3 Hz and the load was 294 N. The air-coupled ultrasonic sensor was set over the surface of specimen. The AE signals detected were amplified by 60 dB using a pre-amplifier. The passband was from 150 to 250 kHz and the trigger level was 7 mV. The resonant frequency of the air-coupled ultrasonic sensor was 200 kHz.

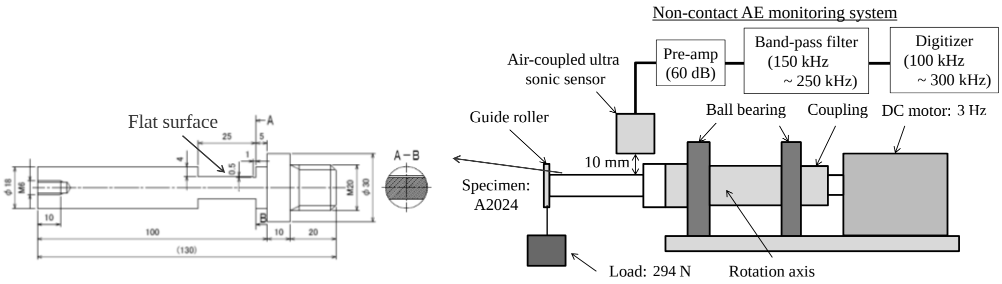

Figure 2: Configuration of fatigue specimen with flat surface (left) and experimental setup for monitoring AE signals during rotary bending fatigue test (right).

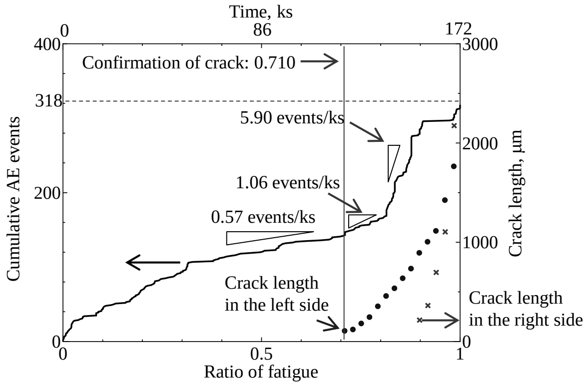

Figure 3:Cumulative AE events and crack length in both side of the specimen.

Figure 3 shows cumulative AE events during the test and crack length in the specimen. The fatigue crack was confirmed at 0.710 of fatigue life on the left side and cracks exponentially increased during the rotary bending fatigue test. From the test initiation, the AE signals were continuously generated. It was indicated that these AE signals before the confirmation of cracks were noise generated by the test machine. From 0.815 to 0.919 of fatigue life, the AE generation rate rapidly increased. It is indicated that fatigue cracks propagation was corresponding to the AE generation rate. Additionally, detection of fatigue crack in rotary component at an early stage can be possible by non-contact AE system.

4. Conclusion

A non-contact AE monitoring system was used to detect AE signals during rotary bending fatigue tests. The AE signals were detected at an early stage of fatigue during the test. It is possibility that detection of fatigue crack at an early stage can be possible by non-contact AE system.

References

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