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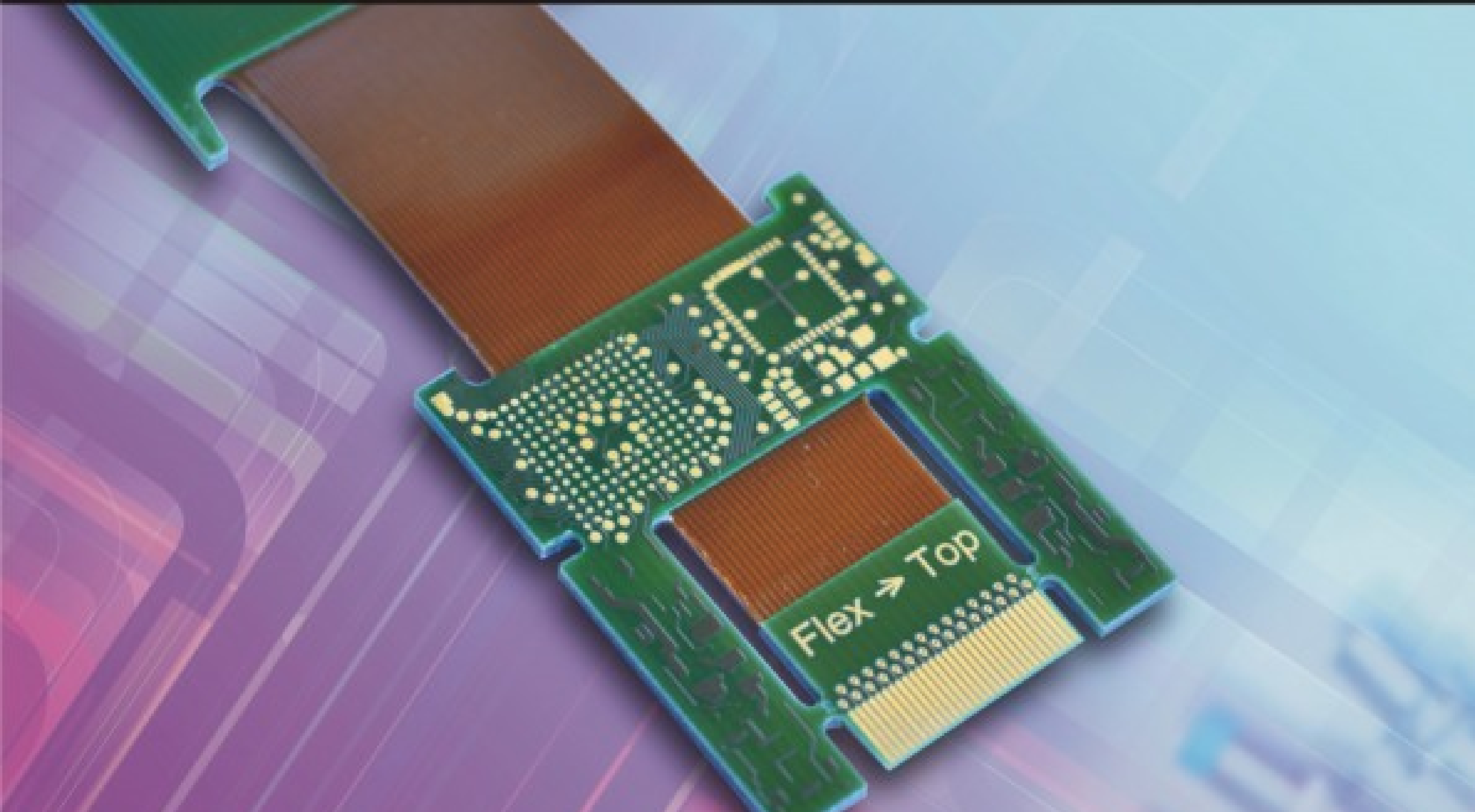

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International Frequency Sensor Association Publishing

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Editor-in-Chief
Sergey Y. YURISH

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Sergey Y. Yurish

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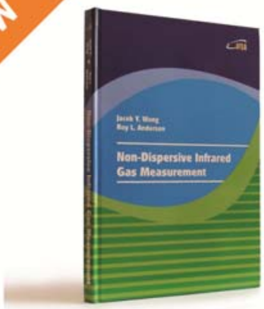

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Acoustic Emission Signal Analysis of Aluminum Alloy Fatigue Crack

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Abstract: Fatigue fracture is the most common failure mode of engineering equipment. It is difficult to monitor the fatigue crack because the fatigue crack is very small. The sizes of fatigue cracks are about several micrometers to several decade millimeters. Acoustic emission (AE) of material is a common phenomenon; In fact, it has relation with the material states. In this paper, the acoustic emission test method about crack is used and the characteristics of different phases of aluminum alloy cracks are analyzed. Practical test shows the AE method could detect the cracks that common method could not detect them. To predict the length of crack precisely is important. AE can predict the size of crack quite well. The result is of practical engineering significance. *Copyright © 2013 IFSA.*

Keywords: Acoustic emission, Fatigue damage, Signal analysis.

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1. Introduction

Engineering equipments often fail while running or not running. That usually causes casualties and property losses. For mechanical structures, fracture is the most common failure mode. However, it is difficult to monitor the cracks while the equipment is running. Acoustic emission (AE) is a common phenomenon. Usually it is the stress wave produced by the sudden internal stress redistribution of the material caused by the changes in the internal structure. Possible causes of the internal-structure changes are crack initiation and growth, crack opening and closure, twinning, dislocation movement, and phase transformation in monolithic materials. Most of the sources of AEs are damage-related; thus the detection and monitoring of these emissions are very useful to predict material failure. Besides the applications of AE in research endeavors, AE has been widely used in industries, including for the detection of faults or leakage in pressure vessels, piping systems, and tanks. AE is also a good method to monitor the welding and corrosion progress [1-7].

Acoustic emissions can be created in a controlled environment, and they can also occur naturally. Therefore, as a means of quality control, the origin of AE is hard to pinpoint. As early as 6,500 BC, potters were known to listen for audible sounds during the cooling of their ceramics, signifying structural failure. After 1900’s, many scientists’ works advanced the research. Joseph Kaiser did a lot of work on AE, and his research is generally recognized as the beginning of modern day acoustic emission testing.

There are two differences between the AE technique and other nondestructive evaluation (NDE) methods; the first difference is that AE detects the activities inside the materials, while other NDE methods attempt to examine the internal structures of the materials. Furthermore, AE only needs the input of one or more relatively small sensors on the surface of the structure or specimen being examined so that the structure or specimen can be subjected to the in-service or laboratory operation while the AE system continuously monitors the progressive damage. Other NDE methods, such as ultrasound and x-ray, have to access the whole structure or specimen, and therefore, the structure or specimen often needs to be disassembled and taken to the laboratory to be examined, the second difference is that AE deals with dynamic processes, or changes, in a material. This is particularly meaningful because only active features are highlighted. The ability to discern between developing and stagnant defects is significant. However, it is possible for flaws to go undetected altogether if the loading is not high enough to cause an acoustic event. Furthermore, AE testing usually provides an immediate indication relating to the strength or risk of failure of a component. Other advantages of AET include fast and complete volumetric inspection using multiple sensors, permanent sensor mounting for process control, and no need to disassemble and clean a specimen [8].

The disadvantage of AE is that commercial AE systems can only estimate qualitatively how much damage is in the material and approximately how long the components will last. So, other NDE methods are still needed to do more thorough examinations and provide quantitative results. Moreover, service environments are generally very noisy, and the AE signals are usually very weak. Thus, signal discrimination and noise reduction are very important [9-13].

2. Specimens and Sensors Layout

A. AE test of tensile specimen

Lots of research results showed that different material has different properties and the same material has the same characteristics. To gain the AE properties of a material, it is necessary to obtain the characteristics of static tensile test. Hereinafter a tensile test of aluminum alloy will be done to get its basic characteristics. The drawing of the specimen is shown in Fig. 1.

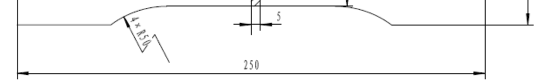

Fig. 1. Tensile specimen.

The instrument which is used in the test is PCI-2 Acoustic emissions instrument; it is a product of PAC Company of USA. The tensile testing machine which is used is WDW-100 tensile testing machine, it is a computer controlled machine, the largest load is 100 KN and the tensile velocity is 1mm/min. Fig. 1 and Fig. 2 are the specimen drawings and sensors layout.

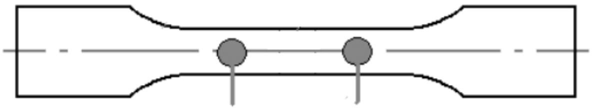

Fig. 2. Sensors location on tensile specimen

B. AE test of fatigue crack

Fatigue failure is a quite common failure mode of Mechanical components. So it is significant to study the behavior of AE of fatigue crack. In this research, the notched specimen is designed as Fig. 3 and the sensors layout is shown in Fig. 4. The sizes of notched specimen are the same as tensile specimen except the notch. The model of fatigue apparatus is PLS-100 electro-hydraulic servo fatigue testing machine. The maximum load is $F_{max} = 100$ KN and the maximum stroke is 50 mm. Fatigue test parameters is as follows: stress ratio: r = 0.1, frequency: f = 10 Hz, mean load: $F_m = 8.8$ KN, load amplitude: $F_a = 7.2$ KN, the cross section of notched part: $A = 85$ mm^2, the maximum nominal stress of the cross section of notched part: $S_{max} = 82.35$ MPa. Based on above data the stress concentration factor of notched specimen is 2.0. When testing, after a certain period, stop the machine and a replica method was used to get the crack shape and size. Then the crack can be measured under microscope and the length of crack was write down, at the same time, the cyclic number was enregistered. When the crack was large enough, it could be observed through reading microscope. To do the experiment, the parameters in Table 1 are used.

Table 1. Parameters of AE test.

Parameters	Values
Frequency (kHz)	100~1000
Preamplifier plus (dB)	40
Threshold (dB)	40
PDT (μs)	300
HDT (μs)	600
HLT (μs)	1000
Sampling frequency (MHz)	5
Highpass filtering (MHz)	0.1
Lowpass filtering (MHz)	1

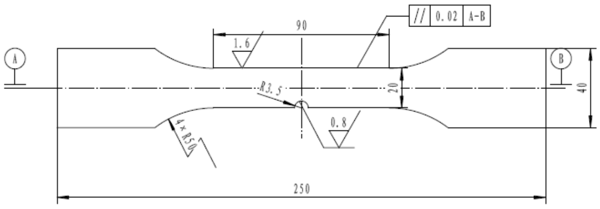

Fig. 3. Notch specimen.

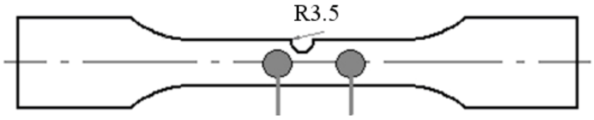

Fig. 4. Sensors location on notch specimen.

3. Results and Discussion

The stress - strain curve of tensile test of aluminum alloy and the counts number every 0.2 s is shown in Fig. 5. The accumulation of counts of AE along with time is shown in Fig. 6. Through Fig. 5 and Fig. 6 it is seen that the curve of accumulation of counts and the stress-strain curve is alike.

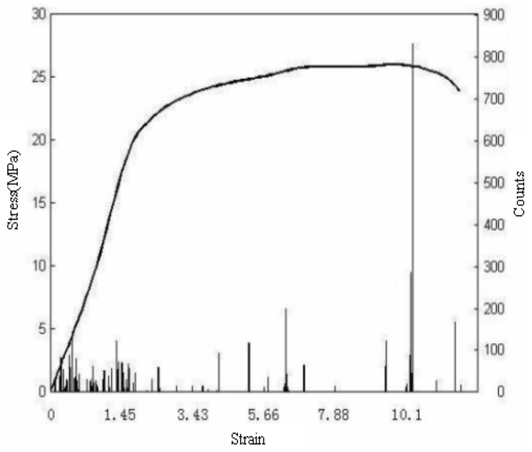

Fig. 5. Stress – strain curve and AE counts.

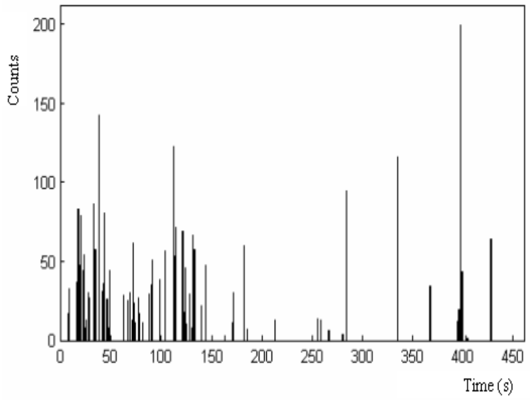

Fig. 6. Time history of counts.

In Fig. 5 and Fig. 6, there are two periods that the AE counts raise quickly; the reason of AE counts increase quickly is the fault of the material and plastic deform, and the reason of AE counts increase quickly is the crack propagation. Fig. 7 is the accumulative curve of counts.

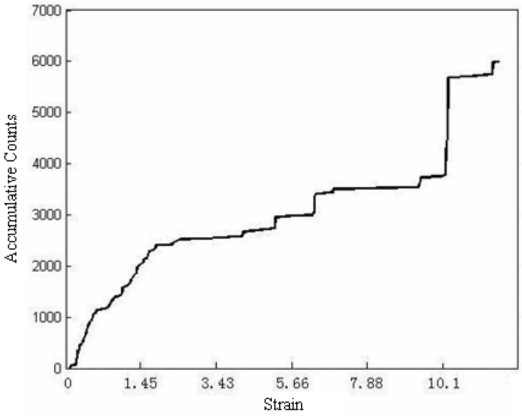

Fig. 7. Accumulative curve of counts.

The fatigue test results of specimens were analyzed. The sensor of the second channel collected the hits, counts and energy signals. Fig. 8 - Fig. 10 are the statistical figures about hits, counts and energy in one second. The Waveform and frequency spectrogram of a single hit are shown as Fig. 11 and Fig. 12.

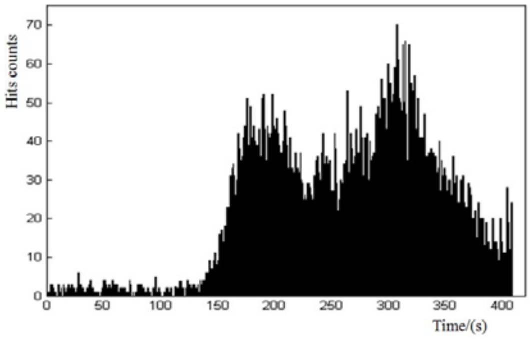

Fig. 8. Statistical chart of hits.

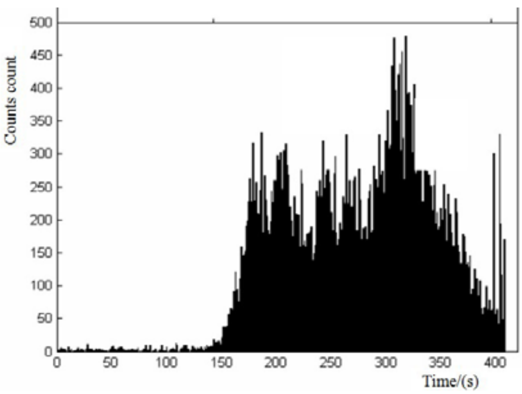

Fig. 9. Statistical chart of counts.

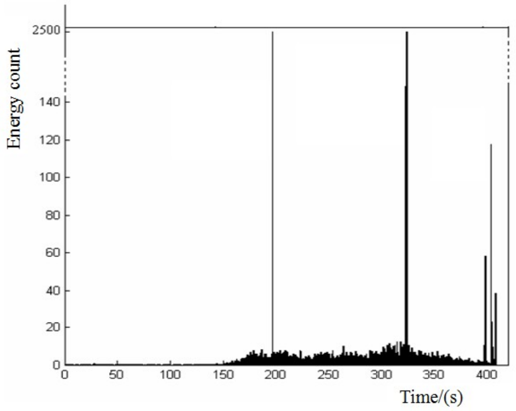

Fig. 10. Statistical chart of energy.

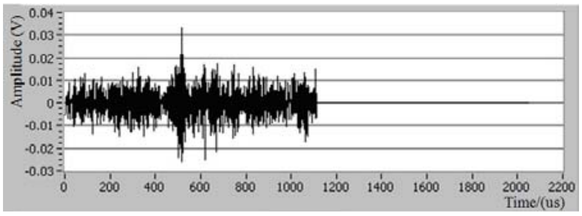

Fig. 11. Waveform of hits.

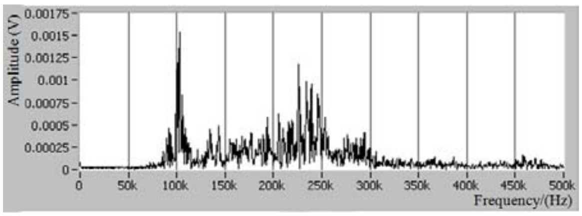

Fig. 12. Frequency analysis.

Through replica method and statistic analysis of acoustic emission signal, it can be seen that the acoustic emission signals of fatigue crack are much more complex than those of tensile test. From test it can be seen the characteristic of are different at different phase of fatigue crack including fatigue crack initiation, fatigue crack propagation and fatigue crack unstable extension. While crack initiation the acoustic emission signals are very weak. When several small crack coalesce, the acoustic emission signals became stronger and with high energy as shown in Fig. 9. In addition, when during the phase of crack quick propagation and fracture, there are a lot of acoustic emission signals sent out. From frequency analysis as shown in Fig. 12, it can be seen that the frequencies of acoustic emission signals are mainly concentrate between 100 kHz – 300 kHz. Usually liquid flow noise of the hydraulic system and mechanical impact noise frequency are less than 100 kHz. However, for the noise of mechanical friction, its frequencies are close to the frequencies of acoustic emission signals of crack. On this occasion, it is difficult to exclude the noise signals by Frequency domain analysis. Through the test results, it can be seen that the energy of acoustic emission signals is larger than the energy of noise signals. In this condition, we can improve the threshold to filter out the noise.

4. Conclusions

AE is a powerful NDT method; in this paper the behaviour of AE of a certain aluminum alloy material is studied. The advantage of AE to detect cracks is that the locations of cracks have little effect on the results. In this paper the properties of AE of fatigue crack are studied. The results shows that the frequency of AE of fatigue crack between 100 kHz – 300 kHz and at different period of crack propagation the characteristics of AE are different. At the period of crack initiation and quick propagation, there are lots of AE signals and the parameters such as counts, hits and energy etc. all changed relatively. When using the auxiliary method such as replica method and microscope method as compare, AE can predict the size of crack quite well; it is significant to engineering practice.

Acknowledgements

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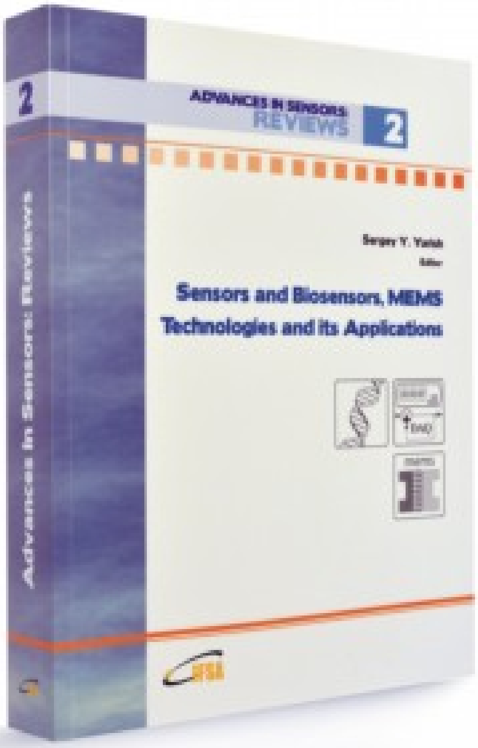
Editor

Sensors and Biosensors, MEMS Technologies and its Applications



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