*APPLICATION OF ACOUSTIC EMISSION TECHNIQUE TO FRACTURE TEST

Zhu Zuming (朱祖铭)
Institute of Metal Research, Academia Sinica, China

ABSTRACT

The feasibility of using the acoustic emission energy technique for measuring the initiation of the crack extension of D6AC steel and commercial pure Ti is examined. It is revealed that the accumulated acoustic emission energy is proportional to the incremental cracking area and it is showed that the relationship between the logarithm of accumulated acoustic emission energy E and the logarithm of the stress $(\sigma-\sigma_s)$ is linear. Thus, it is possible to determine the onset of slow crack growth by a significant change in slop of lgE vs. $lg(\sigma-\sigma_s)$ curve. It has been proposed that the quantitative information about the relative size of a crack can be provided by acoustic emission energy technique.

INTRODUCTION

The acoustic emission (AE) technique has been used to study plastic deformation and crack initiation as well as crack growth in materials[1]. In general we can qualitatively gain the information about the deformation and the fracture of metals and alloys by using AE technique. But at present it is still difficult to measure the deformation and the fracture quantitatively, and the data measured by various experimental methods are not quite consistent with each other. Recently, the AE energy and energy spectrum analysis technique are developed[2]. This paper discusses AE energy technique which has been successfully used to measure the state of cracking tip. The results showed that this new technique is quite useful in fracture study.

EXPERIMENT AND RESULTS

The single-edge notched specimen of D6AC steel with 2.5 × 10 × 120mm was subjected to three-point bending. The length of the precrack on each specimen was a/W=0.45, where W is the width of specimens. The plate specimen with double central notches, which has the thickness of 5mm, the width of 30mm and the gauge length of 60mm, was prepared for tensile test. The material of specimens was commercial-pure α-Ti. The precrack length on each specimen was 2a/W=0.3. The direction of tension was along the rolling direction. The loader was a screw driven testing machine. The compliance gauges were applied to measure the load-point displacement and the crack opening displacement. AE energy rate dE/dt, total energy E, load P and load-point displacement Δ were recorded on multi-pen recorders. The specimens were unloaded at selected different displacement levels and the crack extension that occurred during loading was marked by fatigue cycling. The fracture morphologies of specimens, correspending to different stages of curves of AE, P vs. Δ, were observed with microscope and scanning electron microscope (SEM).

A self-built acoustic emission set was used in experiment. AE signals were detected with a piezo-electric sensor, the resonant frequency of which was 100KHz. The output from sensor was filtered and amplified, then entered the AE energy processor. Threshold voltage used was 0.5V. The total gain of the AE measuring system was 100dB.

1. D6AC Steel

The test was stopped as soon as AE signal was received, the AE energy rate and the corresponding initial crack motion are shown in Fig.1. The initial crack extension was found to be about 0.04mm in length from original crack front, as shown in Fig.1(b). This situation happened within the elastic stage shown in Fig.1(a). Moreover, the more the AE energy was released, the larger the amount of the crack growth was, as shown in Fig.2 and Fig.3. Fig.4 showed the linear relationship between the total accumulated energy of acoustic emission up to the terminated point, E, and the corresponding crack area created, A, obtained for various terminated specimens. This leaded to a simple empirical relationship as follows

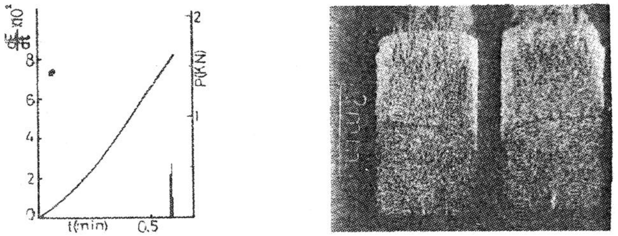

Fig.1 AE behaviour and its corresponding fractograph at initiation of cracking for D6AC steel
(a) AE energy rate (b) fractograph

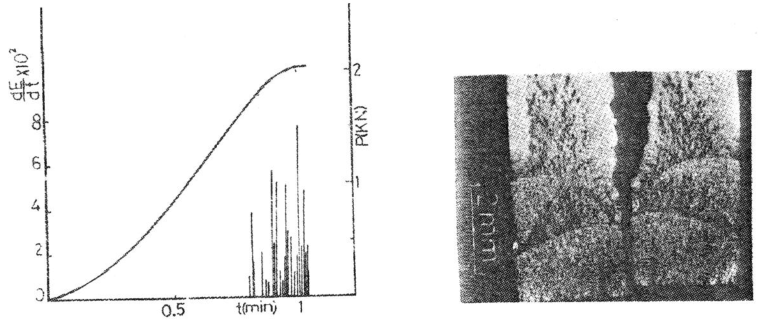

Fig.2 AE behaviour and its related fractograph at mid stage of crack extension
(a) AE energy rate (b) fractograph

$$E = \gamma A \tag{1}$$

where γ is a material constant which depends on the electronic system utilized.

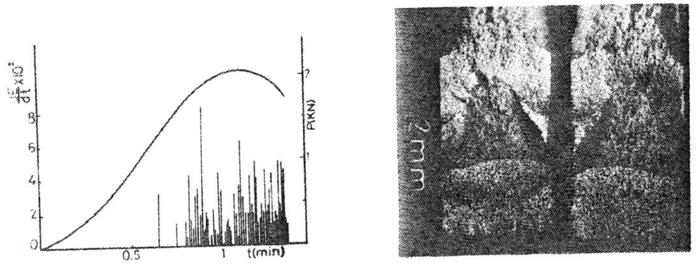

Fig.3 AE behaviour and its corresponding fractograph at later stage of crack extension
(a) AE energy rate (b) factograph

2. α-Ti

A lot of AE signals were detected before crack extension for α-Ti. Fig.5 illustrated that AE energy rate rose rapidly when material was further deformed in large scale. The fractograph showed that there was a continue transition between the fatigue crack zones. But AE energy rate began to drop down during the work-hardening stage, then rose up again as soon as cracking sets in. The fractograph indicated that the crack extension was about 10μm in length along the direction of crack propagation. Furthermore, the AE energy rate dropped down gradually with the extension of crack at this stage, where I and II are the plastic deformation stage and the slow crack growth stage, respectively.

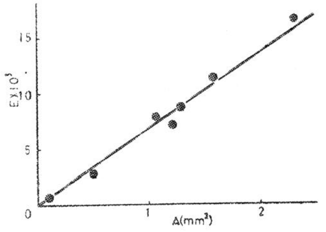

Fig.4 Linear relationship between cracking area created and accumulated AE energy for D6AC steel

The experimental results indicated that there was the following relationship between the total AE energy E and $(\sigma-\sigma_s)$

$$\lg E = m\,\lg(\sigma-\sigma_s) + \lg D \qquad (2)$$

where σ is the applied stress, σ_s is the yield stress, m and D are constants depending on the characteristics of materials. In general, D and m are related to the plasticity and the toughness, respectively, which could be obtained from experimental curves. Fig.6 showed that the experimental data coincided with equation(2) quite well, the turning point corresponded to the cracking initiation.

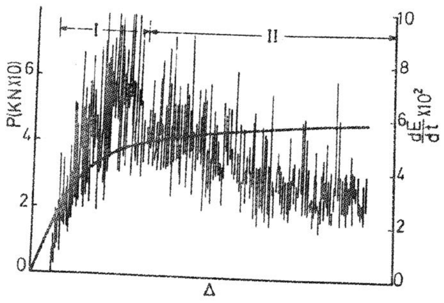

Fig.5 Behaviour of AE energy rate during tensile test

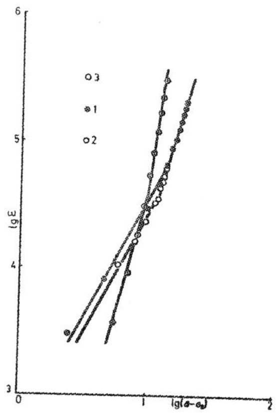

Fig.6 Linear relationship between lgE and lg(σ-σ_s), turning point corresponding to onset of crack extension

DISCUSSION

The observation showed that the plastic zone created per unit time near the precrack tip of D6AC specimen was so small that the amplitudes of AE signals released from the plastic deformation did not excess the threshold level, as a result, no signal could be detected before the onset of crack extension. On the contrary, the dislocations in polycrystalline α-Ti (HCP) moved easily, so the yield stress of α-Ti was quite low. The stress concentration first occured in the zone around the tip of the precrack to make a lot of dislocations multiply and move, accompanying with slip lines and bands, and release much acoustic energy, which could be detected with sensor. The specimens began to flow plastically and heavy slip bands occured when stress was increased further, the acoustic energy per unit time released from specimen was also maximum with the corresponding peak shown in Fig.5. After cracking, a lot of external work was converted into the surface energy needed for the growth of cracks, so the acoustic energy released from specimens decreased. Consequently, the AE energy rate dropped down, as shown in Fig.5. But the stress (σ-σ_s) increased so slow after cracking that the slop of the straight line, $\lg E = m\lg(\sigma-\sigma_s) + \lg D$, began to increase along with the slow steady growth of the crack. Therefore, a turning point occured on this straight line as soon as cracking.

It was clear from experiments mentioned above that the AE energy technique was capable of measuring the initiation of crack extension and the area created at the stage of crack growth, a quantitative information on the relative size of the propagating cracks in turn could be determined. Hence, it is possible to provide the J_{Ic} fracture criterion at the onset of a crack extension and plot a complete resistance curve by using a single small specimen with AE energy technique. Similar results were obtained by Takahashi et al.[3].

CONCLUSION

1. The AE characteristics depended on materials. The AE energy released from α-Ti was more than which of D6AC steel.
2. Total AE energy out of crack growth was directly proportional to cracking area.
3. The relationship $\lg E = m\lg(\sigma-\sigma_s) + \lg D$ was obtained from experimental results, and the cracking point could be measured by using AE energy analysis technique.

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