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Event Energy Distribution in Acoustic Emission - A New Approach

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INTRODUCTION

The analysis of the amplitude distribution of acoustic emission is regarded as a means of describing events taking place during mechanical testing. Since the energy involved with an event depends upon the amplitude levels and their number, this type of analysis is greatly influenced by the frequency band selected and the resolution of the amplitude bandwidth.

By testing six different fracture toughness values of D6ac compact tension specimen Nakamura et al (1) observed the difference in the amplitude distribution between higher and low fracture toughness specimens. They found the slope in the log(event number) versus log(amplitude) tend to decrease with increasing the K_{1C} values. This result is similar to that observed by Scholtz (2) for microcracking during brittle fracturing in rocks and Nakamura et al (1) suggested this may be a universal characteristic of brittle fracture.

Current conventional analysis of the amplitude distribution method was developed originally by seismologists and usually the observations were expressed graphically as log(number of emission) versus log(amplitude). In general acoustic emission observations show a large number of small amplitudes but a much lower number of large amplitude events. However the contribution of the former to the total energy of the emission can be relatively insignificant. In the usual presentation in which the cumulative emission is plotted at fracture, the precise distribution of amplitude and number of events is hidden.

In the present work an alternative method of acoustic emission event distribution is proposed. The carbon fibre epoxy composite undergoing flexural testing has some advantages for the present work over a metallic material regarding in its anisotropic structure and strength.

EXPERIMENTAL

The material used was HM- S carbon fibre in epoxy matrix (CIBA LY558 + HT 973). The loaded mould was placed in a pre-heated press, the plattens of which were thermostatically controlled to maintain a constant temperature of 170°C. The chosen dwelling time was 7 min, in order to minimize the voids content, and left to cure for one hour. No post-curing treatment was carried out. The specimen had a volume fraction of around 47%. (3)

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The mechanical testing was flexural and carried out on a Mays LU50 5-ton load capacity universal testing machine with a cross-head speed of 0.85 mm/min and span-depth ratio of 4;1.

The acoustic emission was monitored during flexural testing using the apparatus briefly described in an earlier paper. A sensor, PZT accelerometer, DJB 1281 was held on the compression side of the specimen by an acoustic couplant and a constant-load spring. The output from the sensor was fed into a non-linear amplifier with a time-delay circuit via a band-pass filter so that only the first-half wave of the emission pulse would be registered by the pulse height analyser of 200 channels. During the test photographic recording of the monitoring TV screen was taken which shows a histogram of the number of emissions and their amplitude. The acoustic emission energy released, E_{aeer}, was calculated from $w^2 \sum N_i V_i^2$ where N_i is the number of emission pulses of height (V_i) and w is the angular frequency. However in the calculation w^2 is omitted since the band-pass filter was set to 180-190 KHz, which is one of the resonant frequencies of the accelerometer.

RESULTS and DISCUSSION

Conventional amplitude distribution in acoustic emission, which originated in seismology, displays the number of acoustic emission events versus the amplitude on a log-log scale and usually such records show monotonically a decrease with increasing amplitude as expressed by $N(V) = A\,V^{-b}$ ...(1) where N is the number of events V the amplitude and A and b are empirical constants. The observed value of b in various materials indicates a large variation and it is not necessarily a materials constant. No physical meaning has yet been attributed to this power relationship and a further complication is that the distribution shows bi-modal distribution (1).

Fig 1 shows so-called amplitude distribution presented in a conventional way, the number of emission and their amplitudes on a log-log scale, for single crystals of NaCl during compression test. The data was taken at the four strains which cover three stages of work hardening involving the transition from the easy glide to second stage of work hardening. A NaCl single crystal shows well defined three stages of work hardening, and during the easy glide slip the hardening is interpreted in terms of the long-range stress between dislocations. In stage 2 slip occurs on additional systems and it is suggested that the hardening is controlled by the forced intersection of dislocations on oblique systems through the dislocation debris. If "amplitude distribution" is to be of any value the change of the hardening mechanism must be reflected in its b value, besides that of A, in equation (1), however, as can be seen in Fig 1 the distinction is hardly visible.

Since acoustic emission is a release of stress wave pulse from a specimen under influence of stress when local instability

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takes place in its structure (microstructure) therefore it is more natural to consider the amount of energy involved with events instead of just considering the number of events. Also it appears natural to consider the potential barrier height (energy level) to be overcome by the specific events instead of simple amplitude. The mechanisms take place in carbon fibre composites during loading to the fracture are, the low energy events like collapse of voids, failure of interfacial bonding between matrix and reinforcement and high energy events like fracture of the reinforcement.

Fig 2a) shows the data in CFRP of the conventional presentation of amplitude distribution, firstly it can be noticed that it is quite impropable to draw any straight line in this case and secondly the significance in number, actually one count, of high amplitude pulse is insignificant in this plot and there is no way to judge the contribution of events to the overall deformation or fracture process. However, in Fig 2b) the same data is plotted, E_{acer} versus V_i^2 on log-log scale and now the Y scale, being the energy unit, the significance of each pulse and event is clearly identifiable. The magnitude of energy release involved with one count of high amplitude can be seen as quite a significant event as regards its energy content.

The variation of event energy distribution with increasing load, at four different load levels, is shown in Fig 3. In the flexural test, specially for the CFRP specimen, there is a great degree of anisotropy in strength, i.e. shear, compression and tensile strengths, therefore, it is to be expected that the fracture of both reinforcement and matrix will occur at the weaker compression side first. In Fig 3 it can be seen that large energy events have already taken place at $\sigma/\sigma_f = 0.64$, where σ is the load applied and σ_f is the fracture load, and the small energy events at higher load level may be caused by the weak events in the tensile zone. It is also noticeable that even a small number of emissions with larger energy content makes far greater contribution to the overall fracture process.

CONCLUSION

The advantage of this presentation of "Event Energy Distribution" with the progress of deformation has been shown in carbon fibre epoxy composite in the identification of specific events taking place. The inadequacy of the conventional presentation of amplitude distribution during the three stages of work hardening in a single crystal of NaCl is shown by the insignificant variation of b factor. However no quantitative relationship between acoustic emission energy release and event energy level has yet been proposed. Calibration of the sensor output relevant to the energy of event requires to be carried out.

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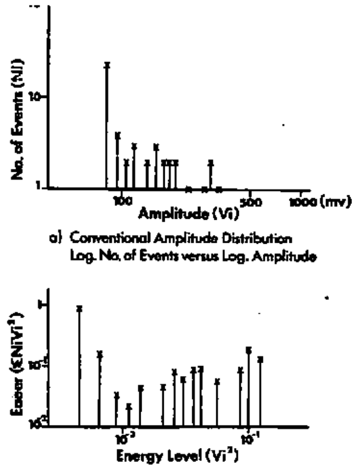

a) Conventional Amplitude Distribution Log. No. of Events versus Log. Amplitude

b) Acoustic Emission Energy Spectra Log. Emission Energy versus Log. Energy Level

FIG 2.

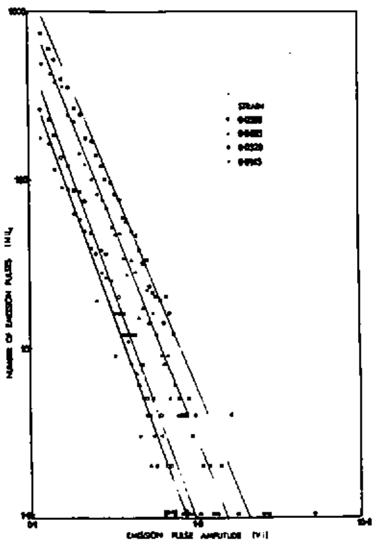

FIG I.

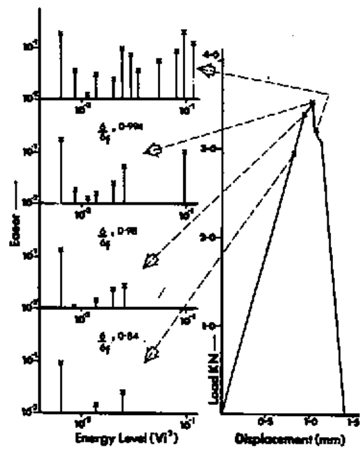

FIG 3.