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Energy Spectrum Analysis of Acoustic Emission Signals

B. Woodward

Loughborough University of Technology

ABSTRACT

This paper is concerned with the characterisation of dynamic defects in solids in terms of the frequency content of acoustic emission "bursts". The magnitude and frequency content of these transient signals depend on the nature of the defects generating them and on the characteristics of the propagation path between defect and sensor. The analysis procedure is to obtain the energy spectrum of each burst and to characterise this by computing a single parameter, the median frequency, i.e. the frequency which divides the spectrum into two equal areas. Provided the propagation path remains constant for each burst, corresponding spectral components will be equally attenuated and any significant differences in median frequency should indicate the presence of different defects. Experiments carried out on "dogbone"-shaped zirconium testpieces indicated that three separate defects (or source mechanisms) produced acoustic emissions. These were identified by a concurrent metallurgical study as twin initiation, twin broadening and slip.

ANALYSIS RATIONALE

The waveform of an acoustic emission burst is a complex decaying oscillation, since it results from the impulse response of a resonant system comprising a solid material and a detecting sensor. Each burst is the observed signature of a very short pulse of mechanical waves generated by some source mechanism, e.g. twinning, crack propagation. It should therefore contain amplitude and frequency information in terms of which the source mechanism can be characterised.

Bursts are generated randomly in time and a sample of them may be represented as a time function x(t). No exact model has been formulated to predict the probability of their occurrence, so mathematically they may be described as non-deterministic and non-stationary. However, bursts can still be characterised statistically and may be analysed in a similar way to stationary random signals. This is because they have finite energy, and therefore a non-zero value for the mean square $\overline{x^2(t)}$, which is related to the energy spectrum (1,2).

In this study, the energy spectrum for each burst is represented by a single point, the centroid of its area. This point is the intersection of the mean energy spectral density - the mean of 500 values comprising the energy spectrum, and the median frequency - the frequency which divides this spectrum into two segments of equal area, and hence equal energy. It is quite conceivable that different source mechanisms, on average, last for different lengths of time. Thus, the effect of different durations would be to change the upper limit of the energy spectra, and this would be reflected in a change in the median frequency.

Unless the propagation path between source and sensor is constant for all bursts, changes observed in their spectra may not be due only to source differences. Using small testpieces and low frequencies (<300 kHz) largely offsets this problem, but to ensure that sources originated within a small total volume the testpieces used were "dogbone"-shaped to give high stress concentrations over a small portion of their length. The testpieces were zirconium sheets 0.7 mm thick and 100 mm long, with a width of 25 mm tapering to 6 mm at the "neck". Their grain diameters were up to 3 mm to aid identification of the several types of defect by which zirconium deforms.

MEASUREMENT PROCEDURES AND RESULTS

The instrumentation included a piezoelectric sensor, a low noise amplifier, a high pass filter with a steep roll-off (>180 dB per octave below 75 kHz), and a 6-speed tape recorder. The system passband was 75-300 kHz. Spectra were obtained from a real time analyser and an ensemble averager. Typical bursts from zirconium lasted 1-10 ms, which was too short to allow for reasonable ensemble averaging; also the frequency content of the signals extended well above the analyser's 20 kHz bandwidth. The signals were therefore time-expanded before analysis by re-recording with an auxiliary tape recorder running at a different speed. The best compromise between frequency resolution and data processing time was to use a time expansion factor of 1024 (2^{10}). The 500 points of each ensemble averaged spectrum were transferred to a PDP11 computer and to an IBM 360/65 computer for processing and graph plotting.

The testpieces were extended by up to 1.5% and were copious emitters of acoustic emission. Generally the differences between the spectra were in their fine structure, but there were large peaks present in some which were significantly absent in others.

Ideally, two separate source mechanisms could be identified if all the computed median frequencies occurred at two frequencies only. However, in practice there was always a wide spread of median frequencies. This spread could not be attributed to changes in testpiece geometry during tensile testing since it was much greater than would be expected from a 1.5% increase in testpiece length. Generally the median frequencies fell into three identifiable groups, indicating the various active source mechanisms. This indication of three mechanisms being present was supported by directly observed evidence (using a TV system) that twin initiation (the dominant mechanism), twin broadening and slip were active in the zirconium.

The upper frequency limit of the instrumentation was only 300 kHz, but if this could be extended to at least the low megahertz region, then differences in the spectra should be more pronounced and thus the source mechanisms with different durations would be more easily delineated.

REFERENCES

(1) B. Woodward, Ultrasonics (1976) 14 249

(2) B. Woodward and R.W. Harris, Acustica (1977) 37 (to be published)