Dependence of Stress Wave Emission upon Brittle and Ductile Fracture Mechanisms

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1. - INTRODUCTION

In the last few years a number of investigations have been carried out in order to clarify the relation between SWE and mechanical variables in FM tests(1,3). However, at the authors knowledge, the problem of the dependence of SWE upon fracture mechanisms has been scarsely investigated.

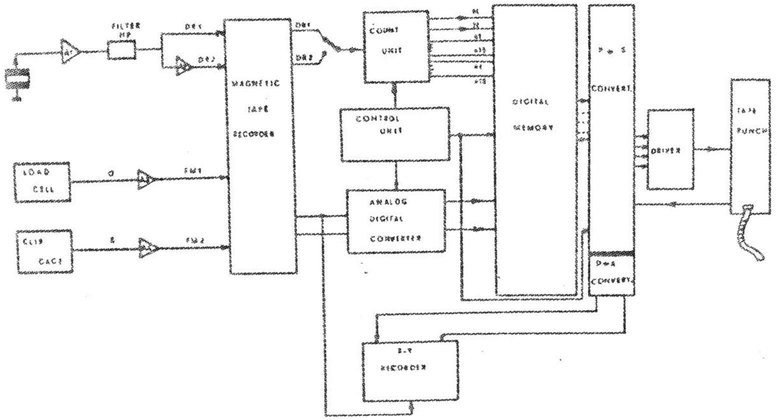
The researches carried out at CSM attempted to examine closely this dependence. Some typical results are discussed in the present paper and qualitatively interpred in terms of dislocations dynamics.

2. - EXPERIMENTAL TESTS

The block diagram of the experimental set-up is given in Fig. 1. The output signals of the piezoelectric transducer are re-

SWE EXPERIMENTAL EQUIPMENT

BLOCK DIAGRAM



corded and processed so as to allow on-line and off-line measurements, in conjunction with a computer.

On line it is possible to evaluate the total count and the count rate as well as the amplitude distribution vs. load and/or extention and/or time. The summation and its time derivative of all oscillations of the struck transducer must not be understood here as total count and count rate.

Our equipment has the unusual feature to allow one to distinguish between a single high energy event and several low energy events occuring in a short time interval. With a PZT-5A transducer having a Q-factor of 30, a resonance frequency 1MHz, a maximum output 5 V, a trigger level for the counter 1 mV, it can be shown that the ring down of thePZT occurs in less than 100 μsec. Thus using a time gate of 100 μsec one can obtain that the count unit gives the increment of only 1 unity, all though at its input many oscillations are present.

The amplitude distribution is obtained dividing the total range 1mV - 5V (74 db) in eight channels. Whenever a pulse of some amplitude strikes the corresponding channel, a definite tension level is present at its output, which can be recorded for instance on an oscilloscope (Figg. 2b, 2b'). The conversion from amplitude V (volt) to energy E (erg) is then operated through the relation

$$E = (5 \times 10^3 \text{ erg/volt}^2) . V^2$$

The calibration is carried out striking the PZT-5A transducer with pulses of wellknown energy, supplied by a little ball falling from different altitudes.

The PSD meaurements are carried out off-line. As second transducer an accelerometer (resonance frequency 11 KHz) is used. After the registration on the magnetic tape, the signals are sent to a Fourier Spectrum Analyser[*] and then averaged by a Spectrum Averager[**]. The results are presented in Figg. 2c, 2c'. They are obtained on FM specimens of 38NiCrMo4 high strength and Fe 52 D low strength steels with a 25 ton Instron test machine. The measured resonance frequency of the machine specimen system is about 250 Hz.

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[*] Federal Scientific - Ubiquitous Mod. 21A - 14.

3. - RESULTS AND DISCUSSION

In Figg.2a, 2a' the load-displacement and summation-displacement curves are presented We notice that while a decrease of the trend of the count rate is apparent in the case of ductile fracture, a monotonic increase characterize the brittle fracture. Keeping in mind our counting procedure, we deduce that the events occuring before failure are more probable in ductile than in brittle case. On the other hand the acoustic signal is originated by a variation of the dynamic state of dislocations groups. It is thus reasonable to conclude that in the ductile case the number of dislocations which are put in motion so as to become detectable is large also at COD values much lower than the corresponding ones at fracture, and that the velocity distribution of the moving dislocations has a spread larger than in the case of brittle fracture.

According to this view the results of Figg. 2b, 2b' indicate than in the brittle case there are only few low energy (0.02 erg) pulses before the fracture; while in the ductile case a wide variety of pulses of energy ranging from 0.02 to 1250 erg are emitted.

To explain the Power Spectral Density behaviours in Figg. 2c, 2c', one should take into account all the factors influencing the frequency content of the single pulses. In fact the transfer function of the transducer, the geometry of the specimen, as well as the attenuation and distortion vs. the frequency of the original pulse due to the microstructure of the material, play an important role in determining the measured spectra. But if these measurements are

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[**] Federal Scientific - Spectrum Averager Mod. 10-14.

carried out under the same conditions, it is reasonable to ascribe the observed differencies to the different modes of fracture.

Thus if the assumption is correct that before the brittle fracture the average dislocation velocity is low and the velocity distribution function narrow, we have to expect a PSD with a well defined peak near some frequency related to the maximum velocity, and shifted towards low frequencies if this velocity is low.

On the contrary, before ductile fracture, characterized by a broad velocity distribution function and comparatively high maximum and average velocity values, a PSD is expected shifted towards higher frequencies in a broader range.

4. - CONCLUSIONS

Our experimental results show a strong dependence of the usual SWE parameters (e. g. total count, energy distribution and power spectral density) upon fracture mechanisms. To explain these results the assumption has been made that the controlling factor of acoustic emission is the velocity distribution of the moving dislocations.

Metallurgical and mechanical variables such as heat treatment, microstructure, segregations, inclusions; strain rate and temperature which affect this distribution, are also expected to give rise to different SWE patterns.

Therefore this technique seems to be very suitable for providing information about the influence of these variables on the fracture processes and studying the nature of the involved phenomena.

REFERENCES

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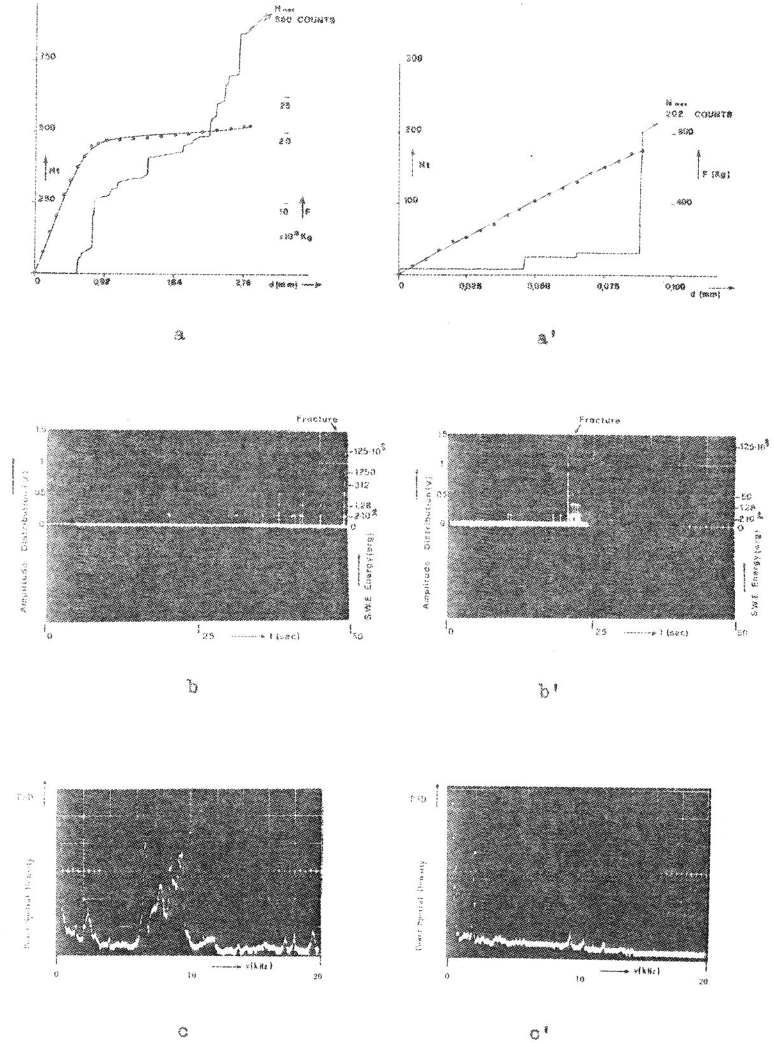

a a'

b b'

c c'

Fig.2 - Total count, Amplitude Distribution, PSD in Fracture Mechanics Tests.
a, b, c ductile - a', b', c' brittle
F load - d displacement