ACOUSTIC EMISSION AS A SUPPORT IN THE IDENTIFICATION OF STRESS CORROSION CRACKING MECHANISMS

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Dynamic evolution of stress corrosion cracking processes has been studied in microstructures with different modelized fracture mechanisms: intergranular, mixed and transgranular. Acoustic emission measurements provide detailed information about process dynamics. The energy of each acoustic emission event, the distribution function of these energies and the evolution of accumulated energy have been used in this study. As a result of this work, it appears that acoustic emission is an important support to the modelling of cracking phenomena, particularly in stress corrosion cracking.

INTRODUCTION

Acoustic emission (AE) has been widely employed as a non-destructive technique in the study of stress corrosion cracking (SCC) (Yuyama (1)). This is owing to the advantages it presents such as the capacity to detect the moment of crack propagation, in same cases the capacity to localise the point of emission using triangulation between several sensors, the capacity to follow the evolution of the propagation process with a very high time resolution, the possibility of estimating the energy emitted in each instant of propagation, and even the capacity of distinguishing the AE pulse sources using spectral analysis of the detected wave forms.

With the objet of supporting the behavioural hypothesis established in the general model of hydrogen assisted SCC in low alloy steels (Gutiérrez-Solana et al (2)), this work has been focused on the study of the AE energy detected in SCC tests.

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The analysis of AE energy is on the one hand based on its evolution in time, to look for information about the dynamics of SCC process, and, on the other hand, on statistical analysis using the accumulated probability distributions of the pulse energy with the aim of correlating them with the type of fracture.

SCC MODELLING

Based on a precise characterization of the SCC behaviour of 41XX steels after various heat treatments, a model of the micromechanisms present in the cracking processes during stress corrosion has been defined (2). The model establishes that SCC occurs because of the existence of a series of isolated and unstable local fractures inside the plastic zone, controlled by local embrittlement due to absorbed hydrogen. These local fractures occur when a critical strain is reached at an appropriate microstructural feature, and are controlled by the strain field and by the hydrogen concentration and distribution in the plastic zone. The model explains the different types of fracture present in SCC, from intergranular to the diverse transgranular mechanisms. The model proposes some processes that are impossible to detect with conventionally instrumented mechanical tests. As an example crack propagates discontinously establishing an incubation time between each two propagation steps. Depending on the propagation fracture type this time may be seconds, justifing the continuous registration of time for the propagation related variables.

The model has also been developed in 2D space, determining the micromechanisms present ahead of the crack tip, which becomes a point. The external optical observation of crack propagation is also in 2D, but real processes occur in a 3D volume of material where crack tip is a line. So once again, a registration of the evolution of parameters associated to the complete 3D propagation phenomena is necessary in order to bridge the gap between modelized and real processes.

AE techniques seem to have the appropriate characteristics to obtain a generalised and continuous information about crack propagation through the measurement of the energy pulses emitted by local fracture processes.

EXPERIMENTAL WORK

Material

A comercial 4140 steel has been used in this work. Three samples have been heat treated to obtain different microstructures, with previously observed SCC behaviour in simulated sea water, that range from intergranular (IG) fracture type (oil-quenched martensite) to cleavage transgranular (TG) fracture type (isothermally transformed bainite). As an intermediate reference, a mixed IG-TG SCC behaviour has been obtained with a martensite-bainite microstructure. Side-grooved DCB specimens were machined, heat-treated and and fatigue-precracked for testing.

Testing Procedure

The samples were tested in simulated sea water environment and subjected to constant displacement to provoke propagation processes with a decreasing stress intensity factor until they stopped at the threshold, K_{ISCC}.

An outline of the experimental facility used is shown in Figure 1. It includes a digital osciloscope for capturing the wave forms of the AE pulses, these are transfered to the computer for data storage. Another completely independent facility is used for study the crack length in the sample, analising variations in its electrical resistance with an alternating current and sincronous amplifier detector technique. Simultaneous measurement using both facilities is an important support in the interpretation of AE results.

ANALYSIS OF RESULTS

As an example of the obtained resuts the evolution in time of the accumulated energy from the AE pulses measured as the integral of the squared pulse voltage amplitude is shown in Figure 2. The representation of this parameter is more adequate than that of the number of counts or pulses because it produces less background noise. Furthermore, the physical interpretation may be more direct because the AE energy cames from the elastic energy released during crack propagation. This leads to the consideration that the accumulated AE energy is proportional to the increase in crack area.

Electrical resistance as a function of time is also represented in Figure 2. The graphics, which were obtained with completely independent techniques, reveal an excelent time correlation between both magnitudes. The measurement of the variation in resistance is associated to the increase in crack area (Hicks and Pickard (3)). From this experience it can be concluded that the measurement of the energy in AE also provides detailed information about the evolution of crack area and indicates the intermittent propagation rate of certain processes, making it possible to observe in detail the successive incubation periods.

The statistical energy distribution has been observed to vary with the type of fracture producing the pulses and for that reason could be a source of further information. The normalised distribution function of the pulse energy in AE for specimens using each one of the heat treatments carried out with IG, TG, and mixed fracture paths verified by SEM, is shown in Figure 3. A series of tests were carried out on each one of these, obtaining a high repetitiveness in the resulting distributions. It can be seen that the slopes of the log-log distribution differ as a function of the fracture micromechanisms. Note that when the fracture path is TG the probability that the pulses are more energetic is greater than in the case of IG fracture paths. This qualitatively agrees with the prediction of the model which says that each local microscopic crack advance occurs inside the plastic zone. The bigger the plastic zone is, the greater is the tendency for the cracks to be transgranular and the size of the microadvances greater. The elastic energy released in each microadvance is also greater, and consequently so is the AE energy of each pulse.

CONCLUSIONS

The methodology used, based on the AE technique has been shown to be capable of detecting the variability of the SCC phenomena, being a great help in the comprehension and modelisation of the micromechanisms present in these processes. The measurement of the accumulated energy and its distribution function provides important data about the propagation sequence and the type of fracture involved.

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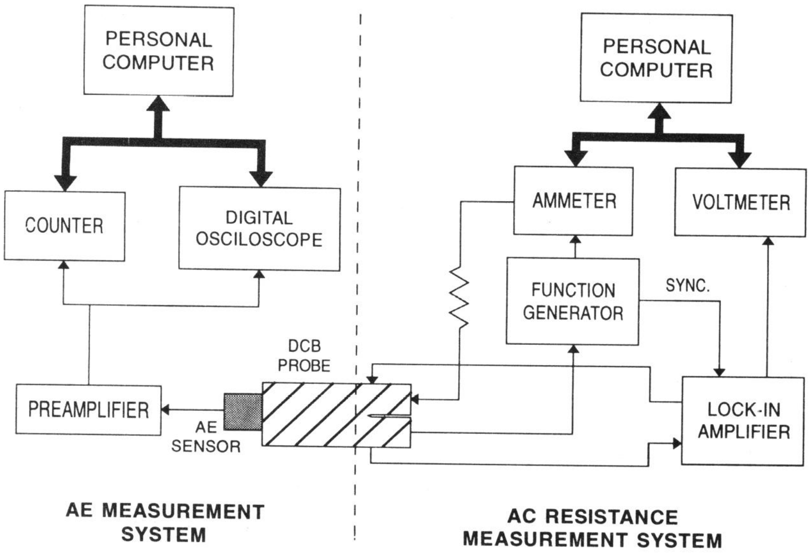

Figure 1 Experimental setup for simultaneous measurement of AE and electrical resistance

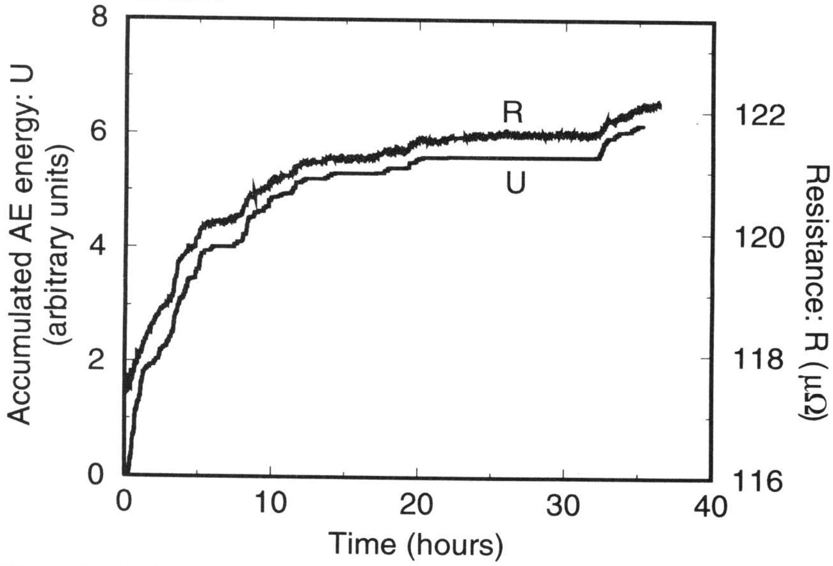

Figure 2 Evolution of accumulated AE energy and electrical resistance in a test of TG fracture path

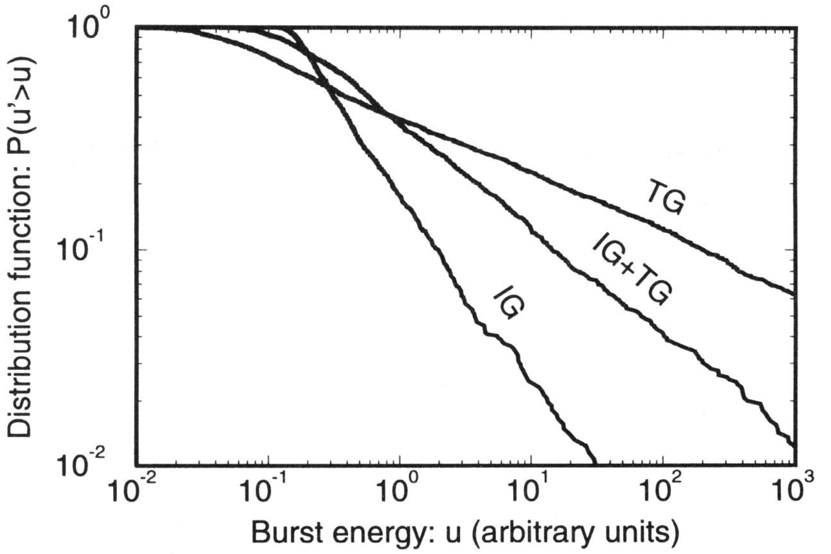

Figure 3 Distribution function of pulse energies for three different types of fracture mechanisms