An Acoustic Emission Pattern Recognition Method for Carbon Steel during Tensile Test

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Abstract. Acoustic emission (AE) method to increase safety and reliability in structural components has become a topic with prime importance in recent years. Therefore, a proper understanding regarding AE sources of damage and fracture mechanics in materials and components is extremely important nowadays. This paper proposes an investigation of the AE signal pattern through measurements performed during tensile tests of specimens in standard S355 carbon steel. A pattern recognition method based on frequency feature and AE signal energy was developed to identify the sources’ signal stage decision during the test. The test presented was carried out by step loading procedures under a constant displacement speed allowing the identification and validation of different AE phenomena.

Introduction
Acoustic Emission analysis has been developed into a very powerful tool for the detection and monitoring of crack propagation [1]. Typically the AE signals recorded during the failure process contain information concerning the characterization of the mechanical behaviour [2]. Recent studies have been carried out regarding the classification of signals resulting from the plastic deformation or crack growth. Pattern recognition method based on average frequency, absolute energy is proved of much help in analysing the damage stage [3, 4].

Material and Specimens
The material used in this investigation was a S355 low carbon steel grade often used in construction, manufacturing and offshore industries. Test specimens were manufactured according to the ASTM E8/E8M-09 with a length of 450 mm to be able to correctly identify the AE reflections and to install the sensor with the required holders. The dimensions of the dog bone specimen are shown in Fig. 1 and the manufactured specimen in Fig. 2. Prior to the test, a 1.5 mm deep notch was created in the middle of the specimen boundary in order to control the crack position initiation.

Experiment Procedure
A Vallen AMSY-6 data acquisition system shown in Fig. 3 was used to measure the AE signals resulting from the material damage and crack propagation. The test was carried out in a step loading way using constant displacement speed of 1mm/min and five stops (load realise and reloading).The loading history is shown in Fig. 4, the first stop was in the elastic region, second stop is during the yielding region and the following three stops were during the strain hardening region. A clip gauge was installed to measure the behaviour regarding the crack opening.

Five different types of AE sensors were used (Fig. 5.) The objective is to compare the pattern waveforms detected by sensors with different resonant frequency. The peak frequency range and distribution of the
spectrum magnitude of these waveforms will help discriminate AE parameters. The sensors details are in Table 1. During the test, a filter of 95 kHz to 850 kHz was applied for all the sensors except for VS 30, to which a band pass of 25 kHz to 850 kHz was defined. An external preamplifier was applied to the PI sensor with the gain equals to 40dB, and the others have built in preamplifiers.

<table>
<thead>
<tr>
<th>Sensor Name</th>
<th>Features</th>
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<tbody>
<tr>
<td>VS 900 (Vallen)</td>
<td>wide band frequency response over the range of 100-900 kHz, Gain=34dB</td>
</tr>
<tr>
<td>VS 375 (Vallen)</td>
<td>375 kHz resonant, middle frequency range, Gain=34dB</td>
</tr>
<tr>
<td>VS 150 (Vallen)</td>
<td>150 kHz resonant, frequency response over the range of 100-500 kHz,</td>
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<tr>
<td>VS 30 (Vallen)</td>
<td>Gain=34dB</td>
</tr>
<tr>
<td>(PI)</td>
<td>Low frequency range (shear wave sensitive)</td>
</tr>
</tbody>
</table>

Table 1. AE Sensors Features

Experiment Results Discussions

The AE test results in Fig. 6 show each stage of the tensile test has their own specific patterns. From Fig. 6(a) it is possible to correlate the increased peak amplitude value of AE signals with the damage on the specimen, the higher values occur when the crack propagation starts (transition between the yielding and strain hardening region). From Fig. 6(b) it is possible to identify the frequency pattern of the different stages and crack openings, higher frequency waveform on the transition between elastic and plastic region. Fig. 6(c) shows that the possibility of monitoring the crack opening using the cumulative energy curves which proves to be a promising structural health monitoring methodology.

![Image](image1.jpg)

(a) AE Peak Amplitude versus loading

(b) AE average frequency versus loading

(c) AE cumulative energy versus loading

Figure 6. (a) Peak amplitude vs Time (right) Load vs Time (Left), (b) Frequency average vs Time (right) Load vs Time (Left), (c) Cumulative Energy vs Time (right) Load vs Time (Left).

Conclusion

The AE average frequency results obtained by the step tensile test proved that the AE characteristics of different regions can be identified, showing clear different patterns between the elastic region or plastic region such as yielding (damage creation) or strain hardening (crack opening). Another important aspect validated with these tests was that AE activity would not happen unless the reloaded value is higher than previous maximum (The Kaiser Effect). Finally, it is proved that AE energy and average frequency are two crucial parameters applied into the pattern recognition methodology for AE waveforms.

References