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# STUDY OF ACOUSTIC EMISSION DURING TENSILE TEST OF MILD STEEL PLATE

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## ABSTRACT

Acoustic emission (AE) technique is widely used for studying deformation and fracture behaviour of materials. An acoustic emission is the elastic energy that is spontaneously released by materials when they undergo deformation. In this study, an attempt has been made to investigate the AE signal generated during tensile test of mild steel plate (ASTM A-370 standard) with 6 mm thickness at room temperature, after that the generated AE signal was compared to the conventional tensile result to get their correlation. AE monitoring was carried out using AE sensor by placing directly on the shoulder of the specimens. The AE signal output from the sensor recorded for every second using the computer system with the LabView™ software. The result shows that the AE signal generated from all specimens is rapidly increases in the elastic region. Meanwhile, in the yield region AE signal shows the maximum value and after that AE signal decreased exponentially with the plastic deformation. Then, the generated of AE signal is low and achieved nearly the ultimate strength and after that it was low or nearly zero. It is concluded that the initial of plasticity, particularly at or near the yield stress contribute to the highest level of AE observed on a tensile curve.

## INTRODUCTION

Acoustic emission (AE) is the elastic energy that is spontaneously released by material when it undergoes deformation. In the early 1960s, a new non-destructive testing technology was born and it was recognized that growing crack and discontinuities in pressure vessels could be detected by monitoring their acoustic emission signals. Acoustic emission is widely used and it is also called stress wave emission, stress wave, microseism, microseismic activity and rock noise [1]. Formally, acoustic emission is defined as the generation of transient elastic wave during the rapid release of energy from localized sources within materials [2]. The source of the emissions in metal is closely associated with the dislocation movement accompanying plastic deformation and the initiation or an extension of a crack in a structure under stress. Other sources of acoustic emission are melting, phase transformation, thermal stress, cool down cracking and yielding process. The technique involves attaching one or more ultrasonic sensor to the object and analyzing the sound wave using computerized equipment. Normally, acoustic emission frequencies are in the range of 150 to 300 kHz.

In this study, the application of acoustic emission is to get the correlation between tensile properties of mild steel to acoustic emission criteria. Mild steel or low carbon steel is selected because this material is successfully used in industrial application such as pipelines, offshore structure and pressure vessels. Such of these steels generally have low acoustic emission. More ever, some of this steel has the level of acoustic emission that varied depending on the orientation of specimens. Therefore, to get the best result all the procedures for tensile test and acoustic emission monitoring should be followed. In this study, high sensitivity AE sensor and computer system with International Measurement LabView™ software was used to monitor and analyze the acoustic emission signal. After that AE data recorded compared to the conventional tensile result to get the correlation, and the final result shown on graph form.

This study is also to investigate the mode of failure and others properties of tensile test on mild steel specimens. In this paper, all the result was compared to the theoretical and also the results from other case studies.

## RELATED WORK

Most of the microscopic processes occurring during plastic deformation involve some stress relaxation, the magnitude is dependent upon the particular process itself, and monitoring AE from a deforming sample can give significant information about the microscopic mechanisms involved in these processes at different strain or stress levels. It is for this reason, in recent years various attempts have been made to correlate AE with dislocation motion and multiplication processes.

An attempt has been made by Jha and Bakdev [3] to compare the acoustic emission generated during Luder's band formation and uniform tensile plastic deformation in mild steel at ambient temperature. Time domain, frequency domain and amplitude distribution mode of data analysis have been used to study these phenomenon. They found that AE captured during Luder's deformation is strong and burst type whereas, AE generated during uniform deformation region is weak and continuous type. Nucleation of Luder's band as a result of dislocation unpinning in undeformed slip system is responsible for large and burst type AE. During uniform deformation region, the rate and amplitude of pulses are low owing to the absence of high energy dislocation processes. Luder's band nucleation and uniform plastic deformation region show characteristic frequency spectra.

Deci Report [4] used AE to analyze a graphite-epoxy honeycomb panel. Based on this analysis it was concluded that it make no difference on which side of the panel a transducer is located for detecting AE signal.

Heiple and Carpenter [5] made observation to AE signal during tensile test of steel A533 (oil quenched) at $650^0$ C. They found that the resulted AE signal shows the increment of AE RMS (root mean square) voltage if the material achieves the yield region, but this AE RMS voltage will decrease and stable if the material starts to enter the plastic region.

Hartbower *et al.* [6] studied tensile test on a few material specimens to investigate the relationship between AE and unstable happenings caused by existing crack that performed during the material under tensile testing. They found that the amplitude of AE signal increased at the point where the planes strain of the material starting to be unstable. The increment of AE signal amplitude and AE rate show that unstable condition has been performed on the plane stress of the material.

## EXPERIMENTAL

Briefly the experimental technique used in this study is shown in Figure 1. The first step is specimen preparation and the last step is analysis of the result.

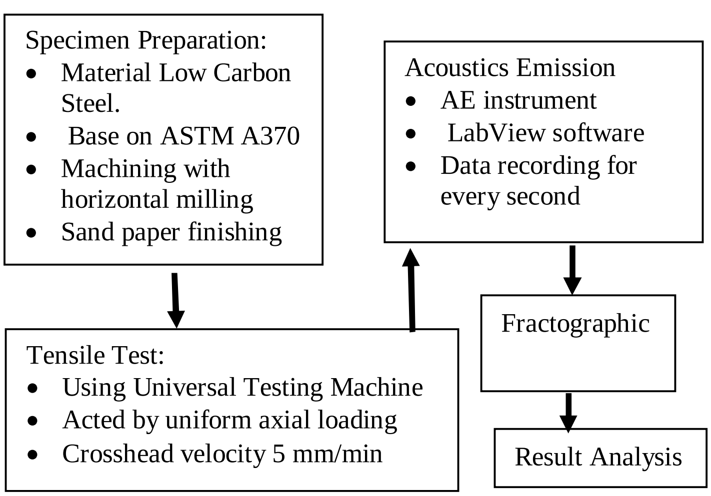


**Figure 1** Flowchart of experimental technique

### Material and Specimen Preparation

The material used in this study was 6 mm thick plate of Mild Steel (Low-Carbon steel) AISI 1020 of composition (in weight %) c-0.2 Mn-0.45 and Si-0.2. Preparation of the specimen based on ASTM A370 using horizontal milling machine and finished by sand paper on the surface. The dimensional details of the specimen are presented in Figure 2 [7].

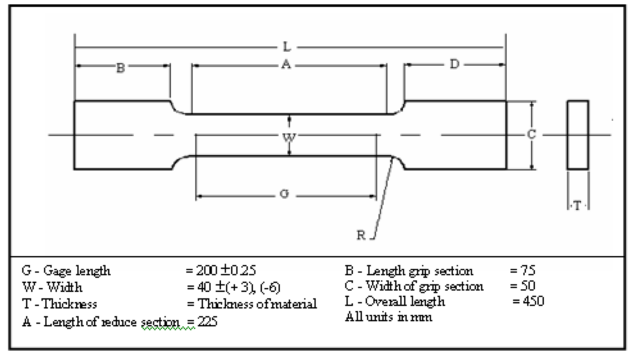


**Figure 2** Dimensional detail of tensile specimens

### Tensile Test

In this study, tensile test for all specimens was performed using a GT-7001-LC10 Universal testing Machine under uniform axial load control condition. Before testing, the gage length and other dimension of specimens was inserted to computer system. Condition of specimens between upper and lower grip are set to $90^0$. Refer Figure 3. The cross heat velocity set to 5 mm/min. All the result was automatically recorded by computer in the graph form. A sample laboratory sheet is shown in Figure 4.

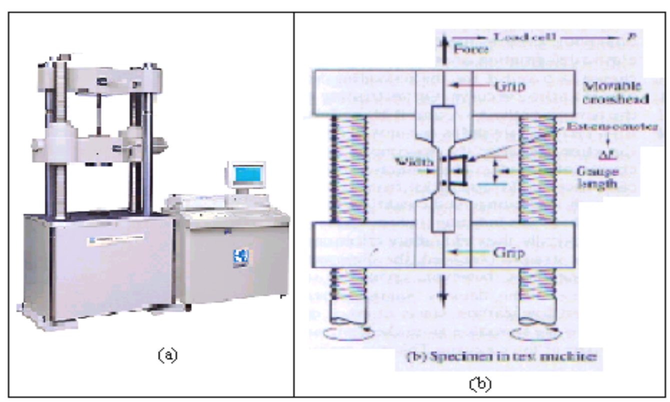


**Figure 3** Specimen setting at grip of GT-7001-LC10 machine

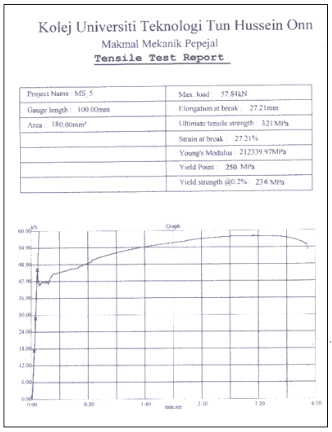


**Figure 4** Sample laboratory sheet for tensile test result

### Acoustic Emission Monitoring Technique

In this study, AE monitoring was performed using AE system with AE transducer, Converter, Ultralspan Dynamic, AC/DC power supply unit, Computer system and LabView 6.1 computer program. The system is as shown in Figure 5. On the LabView programming, the data logger system was used. Acoustic emission data was recorded for every second and converted to excel format for graph plotting. Data logger on the LabView 6.1 is shown in Figure 6.

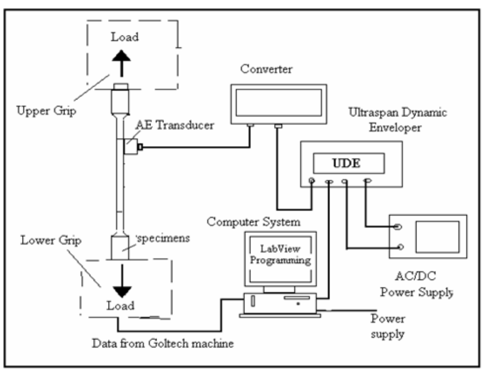


**Figure 5** Schematic of acoustic emission facility and test schemes

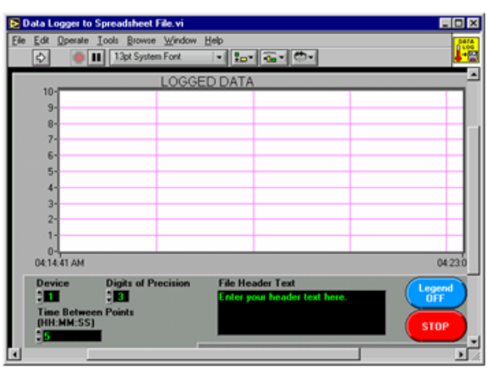


**Figure 6** Data Logger on the LabView 6.1 software

### Fractographic Test

To study the mode of failure of tensile specimens, the SEM Machine type LEICA Stereoscan 420 as shown on Figure 7 has been used. This SEM machine is used to analyze the failure on the fracture surface.

**Figure 7** SEM type LEICA streoscan 420

## RESULTS AND DISCUSSION

### Tensile Test Result

The result of tensile test is shown in Table 1. The value of ultimate tensile strength was calculated using equation $\sigma = P_{max} / A_o$ [8] where $P_{max}$ is maximum load and $A_o$ is initial area. Referred to Norman [9], it was reported that the similar result in the range tensile properties of low carbon steel. Also referred by Mangonon [10], the result of this tensile test was in the range of properties of low carbon steel.

**Table 1** Tensile specimen result as tested at GT-7001-LC10 machine

| No. Specimen | Yield strength (MPa) | Ultimate Tensile Strength (MPa) | Yield Strength at 0.2% (MPa) | % Elongation |
|---|---|---|---|---|
| 1 | 267 | 317 | 233 | 30.01 |
| 2 | 261 | 322 | 233 | 25.94 |
| 3 | 272 | 345 | 256 | 33.51 |
| 4 | 236 | 325 | 236 | 26.20 |
| 5 | 250 | 321 | 236 | 27.21 |
| 6 | 267 | 317 | 233 | 30.01 |
| Average | 259 | 325 | 238 | 28.81 |

### Acoustic Emission Result

Graph of acoustic emission signal amplitude versus time are plotted and shown in Figures 8 and 9 respectively. Figure 8 was obtained from specimen 1 and Figure 9 was from specimen 2. Referred to the above figures, AE signal was increased rapidly starting at the beginning of monitoring and after a few second this signal decreased exponentially with the time. The complete result for all specimens is shown in Figure

10. Similar graph is also shown in the literature when the graph AE signal versus strain was plotted for the low carbon steel and 7075-T6 aluminum alloy [11].

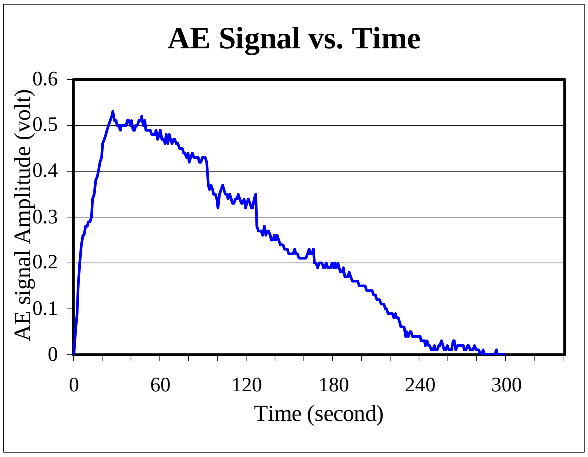


**Figure 8** AE signal monitoring graph plotted from specimen 1

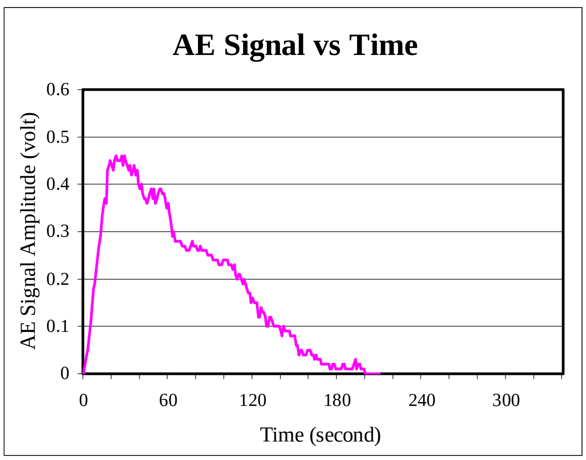


**Figure 9** AE signal monitoring graph plotted from specimen 2

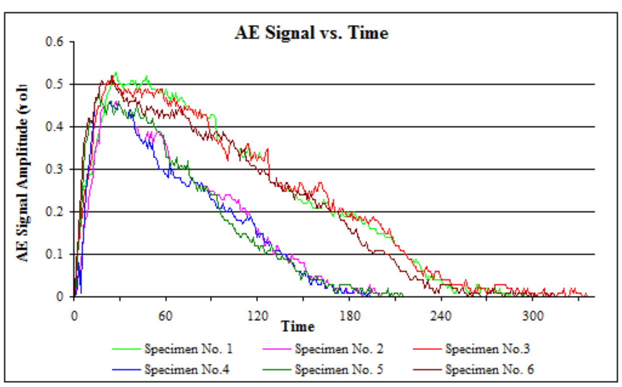


**Figure 10** AE signal monitoring graph plotted from all specimens

Comparative study between the graphs for these AE monitoring and tensile test curve or the correlation between AE signal and tensile test properties are shown in Figures 11, 12, 13, and 14. From these graphs, during the material in the elastic region, AE signal are rapidly increased. In material yield region, AE signal shown the maximum value and this value are constant for a few second. When the AE signal decreased, the tensile curve shows that the specimen was in the plastic region and also nearly in the initial fracture region. Lastly, when AE signal nearly zero the tensile curve shows the specimen nearly the failure mode. Figures 11 and 12 have shown the correlation between AE signal and tensile result in term of force versus elongation. Meanwhile, Figure 13 and 14 have shown the correlation between the AE signal and tensile result in term of force versus time to failure.

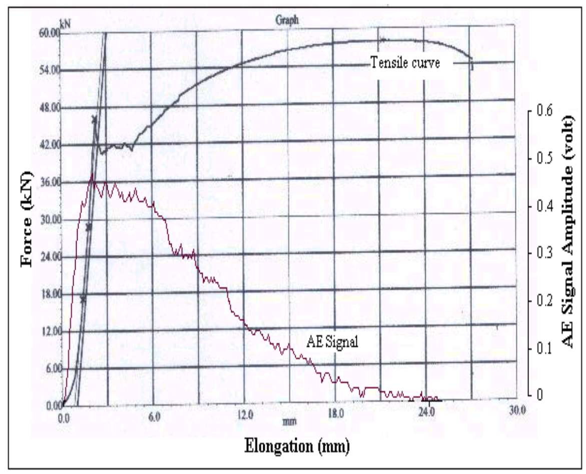


**Figure 11** Correlation between AE signal and tensile result in term of force versus elongation for specimen 5

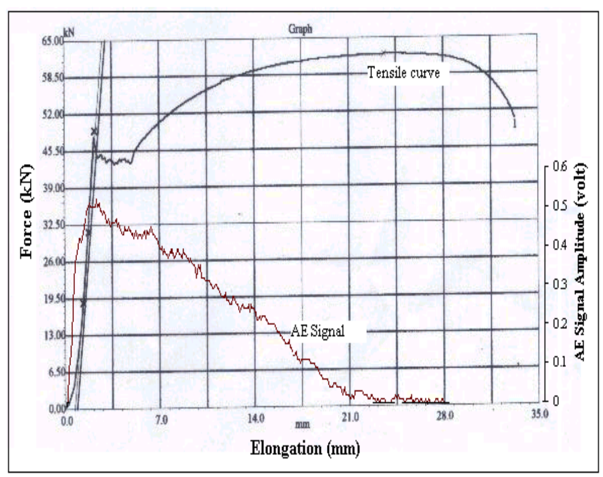


**Figure 12** Correlation between AE signal and tensile result in term of force versus elongation for specimen 6

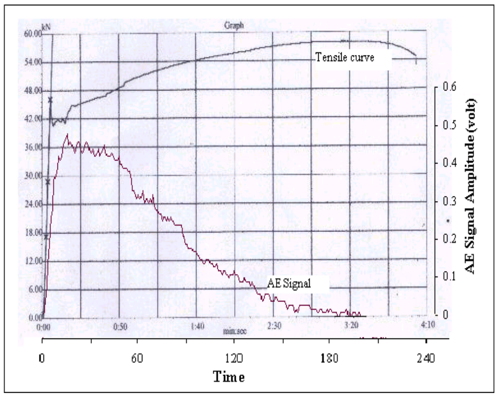


**Figure 13** Correlation between AE signal and tensile result in term of force versus time for specimen 5

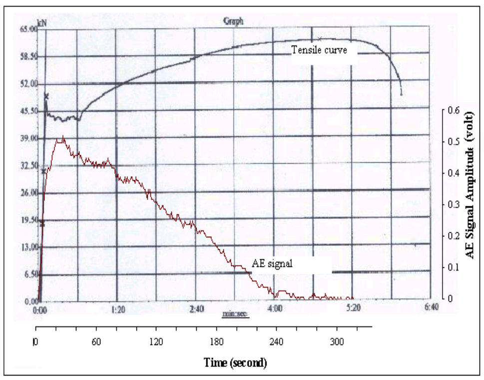


**Figure 14** Correlation between AE signal and tensile result in term of force versus time for specimen 6

### Fractographic Test Result

The fracture surface of the specimens tested from tensile test has been examined under SEM and the fractographs result is presented in Figure 15**.** Based on this fractographs, all the specimens produced both a ductile fracture and $45^0$ shear fractures at the broken surface. It was proved by the existing of small connectivity node (Refer Figure 15 (a) and (b)) and cones (Refer Figure 15 (c) and (d)) at the failure surface of specimens.

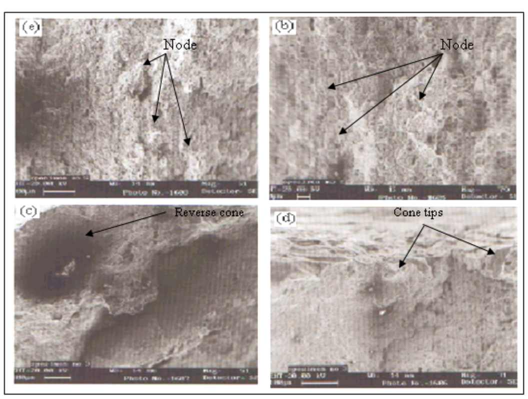


Figure 15 SEM fractographs of the tensile specimen at the fracture surface

## CONCLUSION

From the present investigation, the following conclusions are drawn:

a) Tensile test analysis shows that the results are in the range of properties of low carbon steel.
b) Acoustic emission (AE) analysis shows that the correlation between materials changed during tensile test and the generated acoustic emission signal are exist.
c) AE signal rapidly (linear) increased during the material in the elastic region was the same with incensement of force, stress and strain.
d) Maximum AE signal occurred at the yield stress of the material.
e) The above result shows that the acoustic emission (AE) signal decreased with exponential (approximate) during material in the plastic region and AE signal nearly zero when the material at initial fracture region.
f) Fractographic analysis shown that the types of failure for every specimen are same. It is because the entire specimen acted under same tension force during tensile test of the specimen. The shear force acted between the particles of the specimen.

## ACKNOWLEDGMENT


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