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Incipient Damage Observation of SA 516 Carbon Steel During Tensile Test Using Acoustic Emission Technique

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ABSTRACT

This paper presents the investigation of the acoustic emission (AE) signal technique while detecting and monitoring the incipient damage of the SA 516 carbon steel during the tensile test. For industrial purpose, it is very important to ensure that the maintenance activity should been done before the failure occurred. AE seems to be an appropriate tool to detect the incipient damage due to its sensor capability which can detect up to 1 MHz of frequency. Therefore, the sudden breakdown at the plant can be prevented. The objective of this research is to monitor the AE parameters behavior of SA 516 carbon steel during tensile test using a 100kN Universal Testing Machine with a crosshead speed head of 1.2 mm/min. It was found that the AE activities can be divided into three regions, i.e. elastic, plastic and fracture. The amplitude generated from the AE activities are very high in elastic region and fracture region but low activities in plastic region. This is due to the particle debonding during tensile test when crack initiation and crack propagation occurred. The capability of AE technique will be identified by using cumulative counts parameter. This is to ensure that the AE activity was obtained from the material are only during tensile test. The tabulated data was fitted to the linear relationship with a correlation coefficient of 97%. The value of this correlation is high so that the cumulative count can be used as an indicator to the failure in future.

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INTRODUCTION

The Acoustic Emission (AE) has been used for more than past three decades and widely used in detecting the micro-failure level in all kinds of materials due to the capability to detect crack initiation and propagation until the material fracture. The AE common parameters such as counts, amplitude, hits and energy were used to develop the damage mechanisms. AE is an elastic stress wave generated by the rapid release of energy from localised sources within the material.

Tensile test is the most significant test that can be used to detect the AE activity. Por *et al*. (2012) used carbon steel and welded specimen to detect the differences between the rate of AE hits and force against time. It was observed that each type of materials and welded specimen has its own characteristics. In other research, AE technique has been used to predict the residual strength of post impacted carbon/epoxy composite laminates by using cumulative counts corresponding to the amplitude ranges obtained during the tensile test (Arumugam, V., 2010).

According to the above brief overview, the AE technique can be the most appropriate method to monitor any significant changes inside the material. It is important to understand that the AE behavior starts from elastic point to rupture point. In the present work, the capability of the AE technique for detecting and monitoring the incipient damage of the SA 516 carbon steel during the tensile test is being studied. This material is usually used for fabricating the pipelines and pressure vessel in oil and gas industries and also in automotive industries.

MATERIALS AND METHOD

Material:

The specimen were prepared according to ASTM E8 standard (ASTM E8, 2003) and polished with several grade of silicon abrasive paper in order to remove the stress concentration on the specimen surface. Figure 1 shows the specimen SA 516 carbon steel used throughout this research respectively.

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Fig. 1: Specimen SA 516 carbon steel.

Tensile Test:

The tensile test was performed using a ZWICK BTI FB100kN Universal Testing Machine (UTM) according to the ASTM E8 stardard [2] with the crosshead speed used is 1.2 mm/min. The monotonic properties of the material has been collected. In order to collect the AE data, the AE sensor was attached to the specimen during the test.

Acoustic Emission Monitoring:

Figure 2 shows the complete apparatus for AE monitoring during tensile test. Before each test, the data acquisition system was calibrated by performing a pencil lead break procedure. This procedure is to ensure that the AE sensor is perfectly functioning. In the pre-testing procedure, threshold level of 40 dB was selected after load is applied to the dummy specimen (Hanafi, Z.H., 2010). This is to ensure that the AE sensor detects the signal due to tensile activity only during the experiment. Signals was amplified by preamplifier with 34 dB gain and analysed by AMSY-6 software from Vallen System.

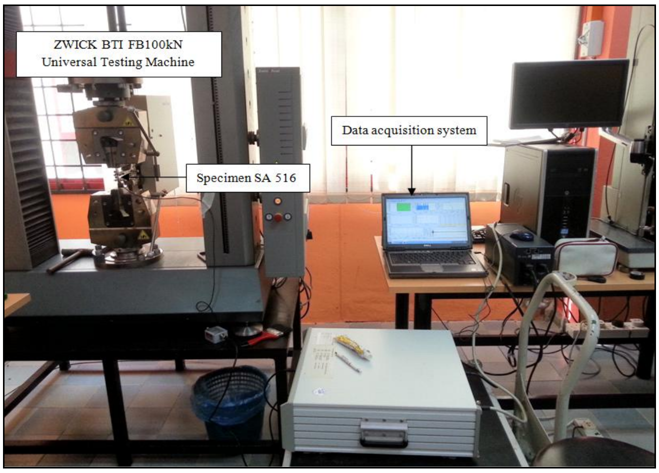

Fig. 2: The complete apparatus for AE monitoring during tensile test.

RESULT AND DISCUSSION

Table 1 shows the monotonic properties of the SA 516 carbon steel obtained from the tensile test. The Young's modulus is used to describe the elastic properties of material which are stretched or compressed. Besides, the ultimate tensile strength of a material is used as indicator of a material limit stress at which the material actually breaks. From this test, it is shown that this material having two values of the yield strength (upper yield strength and lower yield strength). This phenomenon is normal for those materials that belong to the mild steel group.

Table 1: Material properties obtained from the tensile test.

Material Properties	Values
Young's Modulus, *E* (GPa)	219
Stress at 0.2% plastic strain (MPa)	369
Upper Yield Strength (MPa)	374
Lower Yield Strength (MPa)	359
Ultimate Tensile Strength (MPa)	532
Fracture Stress (MPa)	338

Figure 3 shows the recorded AE amplitude during the tensile test. This parameter was selected to represent the AE activities. From the results obtained, the AE activities can be divided into three regions which are during elastic deformation (A region), plastic deformation (B region) and fracture (C region). The pattern of the AE amplitude and stress are significant which gives high amplitude during elastic region (A) and fracture region (C). Generally, when tensile test is performed, the movement of crack will occur and propagated to each other.

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In the plastic region (B), the amplitude of AE signal distribution is low. This is due to the bond strength of particles is weakened during this region and easier to initiate debonding during subsequent tensile test. During the crack propagation the amplitude will be transmitted and will lead to crack detection by using AE sensor (Aggelis, D.G., 2010).

Figure 4 shows both stress and cumulative count that generated from AE signal during tensile test. Count is the number of pulse produced by the AE signal amplitude exceeds a present threshold that has been set. This parameter depends on the magnitude of the AE event and the characteristic of the material. Cumulative counts are the range of amplitude obtained during tensile test. In the elastic region, the cumulative count increases significantly until the specimen break. The distribution of cumulative count can be used as an indicator to predict the failure of the material as the increment of this parameter is in order (Arumugam, V., 2010).

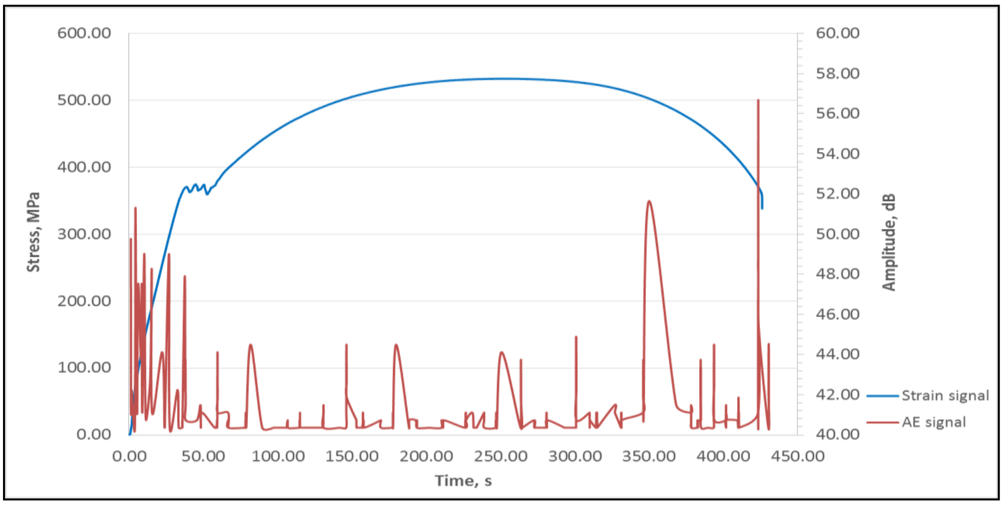

Fig. 3: Trend of AE amplitude during tensile.

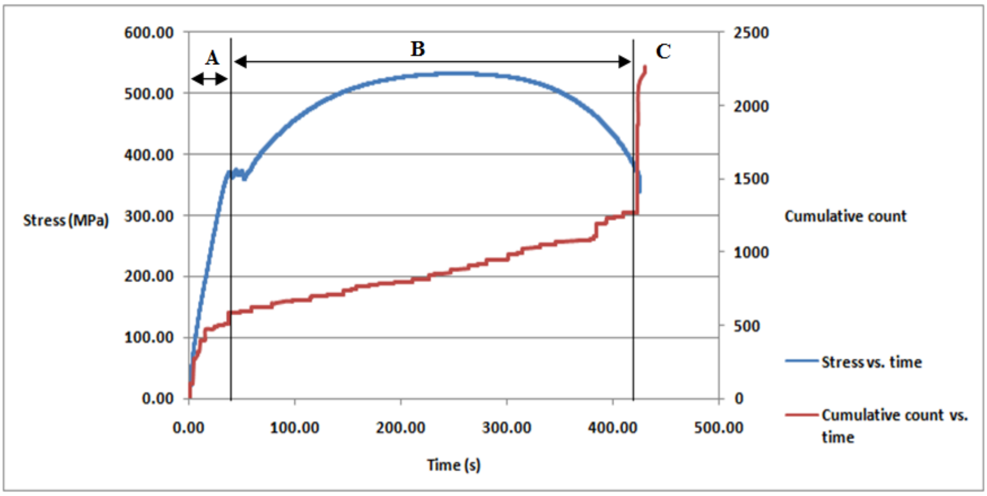

Fig. 4: The both stress and cumulative count that generated from AE signal during tensile test.

In order to show the significant of the AE amplitude in assessing the incipient damage of the material, a correlation between the AE cumulative counts towards the failure time was established. Figure 5 shows the relationship between the AE cumulative count and the failure time during tensile test. The tabulated data was fitted to the linear relationship with a correlation coefficient of 97 %. The value of this correlation is high so that the cumulative count can be used as an indicator to the failure of the specimen in future.

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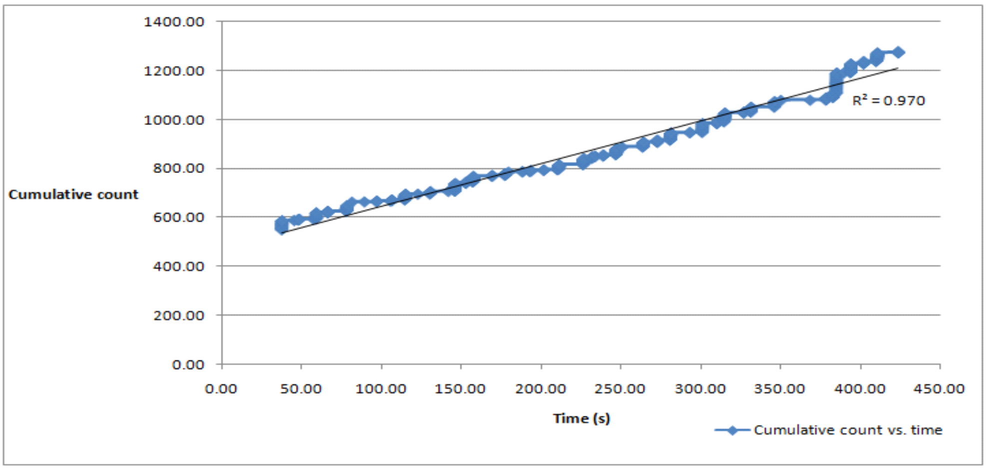

Fig. 5: The relationship between the AE cumulative count and the failure time during tensile test.

Conclusion:

The AE behavior during tensile test deformation of carbon steel SA 516 has been discussed. It was found that the AE activities during tensile the test were very active in elastic region, drop significantly when it starts to enter plastic region and increase rapidly at the rupture point. Based on the result, this method seems to be effective due to its ability to detect and monitor damage stages during the tensile test. Either amplitude or counts of AE activity both produced a good result in order to relate with AE activity during tensile test.

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