A STUDY OF ACOUSTIC EMISSION PROPERTIES ON WELDED A240GR 317L STAINLESS STEEL USING ACOUSTIC EMISSION TRANSMISSION UNDER TENSILE LOAD

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Thesis submitted in fulfilment of the requirements
for the award of the degree of
Bachelor of Mechanical Engineering

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SUPERVISOR DECLARATION

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I declare that this report titled " A Study of Acoustic Emission Properties on Welded A240GR 317L Stainless Steel using Acoustic Emission Transmission under Tensile Load " is my result of own researches except as stated in the references. This thesis / report has not been accepted for any degree and is not concurrently submitted for award of other degree

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Dedicated, truthfully for supports, encouragements and always be there during hard times, to my beloved family

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ABSTRACT

This project presented the study on AE properties of welded A240GR 317L stainless steel using Acoustic Emission Testing (AET) under tensile load. This project were involving three main objectives which is to acquire acoustic emission (AE) data from tensile test on base metal and welded specimens and also to analyze AE properties and find the correlation to the stress-strain curve. Tensile test were used to make the cracks propagation and to analyze the properties based on stress strain curve. There is two condition prepared for the tensile test which base metal specimen and welded specimen. AE piezoelectric sensor were used to detects AE activities during tensile test been conducted. The AE data acquired being selected in number of 30 samples by comparing the waveform for each data. Then it was plotted in Stress and AE properties versus time to get the correlation of tensile activity with AE properties. Results show that the AE activity is high during elastic region before the tensile strength, and it is reduced significantly with respected to the nominal strain and increased back in plastic region until fracture. AE properties were recorded more in welded specimen compared to the base metal because of the defect of welding. Kaiser effect is happened because of the significant reduced of load after tensile strength causing by the dislocation of structure from elastic to plastic region. Acoustic emission technique is widely used in industry to as a condition monitoring technique to monitor the equipments such as pipes and pressure vessels condition.

ABSTRAK

Projek ini membentangkan tentang penilitian pada sifat pancaran akustik (AE) ke atas A240GR 317L besi tahan karat berkimpalan ketika ujian regangan. Objektif projek ini adalah untuk mendapatkan data AE dari ujian tarikan spesimen asal dan spesimen berkimpalan serta untuk mengkaji sifat AE dan mengkaji hubungannya dengan graf tarikan melawan pemanjangan.Ujian regangan dibuat untuk mewujudkan kepatahan dan pergerakan pada spesimen manakala elektrik-piezo sensor digunakan untuk mendapatkan pancaran akoustik. Data dipilih sebanyak 30 sampel berdasarkan bentuk gelombang setiap data dan graf dibentuk dari data dengan nilai regangan dan masa. Keputusan menunjukkan pancaran akustik pada zon elastik lebih tinggi dari zon plastik dan keretakan. Terdapat penurunan dari segi pancaran antara zon plastik dan elastik akibat perubahan keretakan pada struktur. Pancaran akustik pada sampel yang mempunyai kimpalan adalah lebih tinggi berbanding spesimen asal akibat kehadiran kecacatan pada kimpal. Kesan Kaiser berlaku pada antara selepas zon elastik dan sebelum zon plastik akibat penurunan beban secara tiba-tiba akibat perubahan struktur dari elastik kepada plastik. Pancaran akustik digunakan secara meluas dalam industri sebagai suatu teknik untuk mengetahui keadaan seperti saluran paip dan tangki bertekanan.

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LIST OF SYMBOLS

%	Percent
mm	Milimetre
kN	KiloNewton
MPa	MegaPascal
MHz	MegaHertz
kHz	KiloHertz
°C	Degree Celcius
Bar	Bar
N	number of data taken into calculation
σ	standard deviation
Yi	data sample
$\bar{y}$	mean of data
mV	microVolt

LIST OF ABBREVIATIONS

NDT	Non Destructive Testing
DT	Destructive Testing
AE	Acoustic Emission
YS	Yield Strength
UTS	Ultimate Tensile Strength
HAZ	Heat Affected Zone
ASTM	American Society for Testing and Material
RMS	Root Mean Square
Cr	Chromium
FCC	Face-Centered Cubic
BCC	Body-Centered Cubic
SCC	Stress Corrosion Cracking
DBTT	Ductile-Brittle Transition Temperature
Fe	Ferum
C	Carbon
Ni	Nickel
Mo	Molybdenum
Ti	Titanium
TIG	Tungsten Inert Gas
MIG	Metal Inert Gas
MMHE	Malaysia Marine and Heavy Engineering
GMAW	Gas Metal Arc Welding
ASME	American Society of Mechanical Engineer

AET	Acoustic Emission Transmission
PZT	Lead Zirconica Tartanate
TWB	Tailor Welded Blank
CNC	Computer Numerical Control
EDM	Electric Discharge Machining
CO2	Carbon Dioxide

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Pressure vessel is widely used to be as storage for pressurized fluid. There are three types of pressure vessel that is spherical, cylindrical with straight ends or torispherical and cylindrical with hemispherical ends. The end caps are called head. The critical point for pressure vessel is at the weld joint between end caps and body of the pressure vessel and the curving shape of the head. The material for pressure vessel is stainless steel. The welding joint at pressure vessel is a critical issue that need to be looked because it is a major factor that contributes to the failure or disaster of pressure vessel (David, 2001).

The quality of a welding joint can be determined by Non Destructive Testing (NDT) and Destructive Testing (DT). NDT can be related as quality control, quality technology and non contact measurements and concerning on the aspects of characterization of solids, its microstructure, texture, morphology physical and chemical properties as well as the methods of preparation. There is some established and well known techniques and test involving in NDT such as radiography inspection, ultrasonic inspection, magnetic particle inspection, liquid penetrant inspection, thermography and visual testing. Example for DT is tensile test, charpy test, bend test, macro test and hardness test (Derek, 1996). In DT, small number of samples will be taken from weld joint and area around the weld joint to undergo that specific test. Usually it will be done to make a study or to know the mechanical properties of the welded joint and the area affected by heat from welding process.

Inspection of using Acoustic Emission (AE) signal is the new technology in NDT and this technique is getting popular. By use of AE signal is classify under ultrasonic inspection and using the high frequency waves. AE is referring to the generation of transient elastic waves produced by a sudden redistribution of stress in a material. Sources of AE is varies such as earthquakes, rockbursts, initiation and growth of cracks, slip and dislocation movements, melting, twinning and phase transformation in metals (Ndt Resources centre, 2012). Applying the AE signal for inspection is meaningful because only active features are highlighted. It is also providing an immediate detection related to strength or failure of a component.

1.2 PROBLEM STATEMENT

The used of pressure vessels is getting wide and it is applicable in oil and gas industry, power generation industry, plant, laboratories and also in automobile applications such as to store the Nitrogen gas. Hence, the safety of the pressure vessels need to be considered in such a manner so that the consumers have less risk on having and facing the pressure vessels failure operation that brings to the blasting. The critical point that all types of pressure vessels have is at the welding spot. Other critical point is at the bending or curving area of the pressure vessels (David, 2001).

Inspection for pressure vessels need to be done in a interval of time and must be followed the schedule to prevent any loss or injuries. Nowadays, technology had been developed so that the inspection process is getting easier but more efficient and accurate. The acoustic emission signals have been used in the inspection to analyze the activity and crack initiation and propagation in order to find the failure of the pressure vessels. The AE signal is able to detect and characterizes the macro and micro cracks of the structure or pressure vessels. The advantages of using AE in inspection or NDT is the entire structure can be inspect using a single test, limited access required, and it will detect the active flaws in the structure.

1.3 OBJECTIVES

i. To acquire AE data from tensile test on base metal and three welded specimens.
ii. To analyze AE properties and to find the correlation of AE parameters with stress strain curve.

1.4 HYPHOTHESIS

i. Base metal will have higher tensile stress compared to the welded specimens because the welding procedures change the normal grain structure by effecting of heat and solidification.
ii. AE signals captured from welded specimens will give significant different compared to the base metal causing from the non uniform stress contribution at the welded area.
iii. Elastic region will have higher intensity of AE signals than in plastic region.

1.5 PROJECT SCOPE

i. Use the single channel AE sensor to acquire data of AE in the range frequency of 20 kHz to 500 kHz from the tensile test.
ii. Provides specimens for tensile test based on ASTM E-8
iii. The specimen condition is taken at the normal base metal condition and at three different sizes of cracks from welded area.
iv. To get the AE parameters such as number of hit, Root Mean Square (RMS), counts and energy to see the correlation with stress-strain curve.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This project is to study the AE properties during the mechanical test procedures for three types of different condition of materials. It is same in type of material but different in condition. One specimen will be as base metal and other three specimens are from welded specimens.

Based on the title, the mechanical test is by using the tensile test. The standard sizes of the specimens also need to be consider so that the result is acceptable and can be trusted and verified.

Acoustic emission will be used as a method to monitor the crack propagation during the test conducted. The signals from the cracks will be analyzed to find the correlation to stress-strain curve.

2.2 ALLOY STEEL

2.2.1 Basic foundation of Alloy Steel

Metals is such an important materials used in many types of field and applications. Most metals will be melted in the furnace to produce the molten metal before undergo moulding process to make the shape by its demand. Addition of some alloying elements during melt will produce the alloy steels that have different types based on its chemical composition.

Alloys based on iron called ferrous alloys and those based on other materials is called nonferrous alloys (William and Javad, 2006). There are many varieties of alloys such as plain-carbon steels, alloy steels, cast iron steels, copper alloys steels and stainless steels. Even though the steel and cast iron make up the largest use on a weight basis, the numbers of different nonferrous alloys exceed the number of ferrous alloys. By alloying the metals, it can improve the metals properties to be applied in specific application.

2.2.2 Types of Stainless Steel

The famous metal alloys steels that are widely used in industry and application is stainless steels. Its good corrosion, stain and rust resistance criteria makes this types of metal alloys steels such in highly demand. 6 types of stainless steels are ferritic, martensitic, austenistic, precipitation hardening, duplex and super alloys stainless steels. The basic composition for stainless steels is Chromium (Cr) with at least 12% from the total composition. According to classical theory, chromium forms a surface oxide that protects the underlaying iron chromium alloy from corroding and the stainless steels must be exposed to oxidizing agents for producing the protective oxide (William & javad, 2003).

2.2.3 Ferritic Stainless Steel

Ferritic type of stainless steels is an iron-chromium binary alloys that containing of 12 to 30 percent of chromium. Since its contain more than 12 percent of chromium, it is not undergo FCC-to-BCC transformations and cool from high temperature as solid solutions of chromium in α iron (William and Javad, 2006). This type does not have any other alloying elements and it cannot be hardened by heat treatment but can be softened by annealing. Ferritic grades are more resistance to stress corrosion cracking (SCC) in chlorides and caustic alkali media than austenitic grades and it have a good resistance to the oxidation and localized corrosion. However, its disadvantages is relate to susceptibility to intergranular corrosion, low plasticity and toughness, and higher ductile-brittle transition temperature (DBTT) than at room temperature (You et.al, 2007). Moreover, cracking are usually observed at the welds of ferritic grades because of grain coarsening in Heat Affected Zone (HAZ), 475 degree Celsius and high temperature embrittlement, and δ phase precipitation (You et al. 2007).

2.2.4 Martensitic Stainless Steel

The capability of forming a martensitic structure after an austenitizing and quenching heat treatment makes this type of stainless steels known as martensitic type. They are ferritic in annealed condition, but then it will transform into martensitic structure after rapid cooling in air or in any liquid medium kept below the critical temperature for transformation (Neri and Colas, 2001). They have essentially Fe-Cr alloys containing of 12 to 17 percent of chromium with sufficient carbon (C), approximately 0.15 to 1.0 percent (William and Javad, 2006). Martensitic stainless steels would have corrosion resistant and hardenable by heat treating and it is mainly used when hardness, strength and wear resistance are required. Generally, they have higher tensile and yield strength compares to the ferritic stainless steels.

2.2.5 Austenitic Stainless Steel

Austenitic stainless steels are essentially iron-chromium-nickel ternary alloys containing about 16 to 25 percent Cr and 7 to 20 percent nickel (Ni) (William & Javad, 2006). The ability of maintaining its structure in austenitic (FCC, γ iron type) because of the presence of nickel element at normal heat-treating temperature makes this type of stainless steels known as austenitic. Generally, this type of stainless steels is not suitable to undergo welding process because it is containing carbides that will precipitates at grain boundaries and producing intergranular corrosion. But, this problem can be solved by reducing the carbon (C) content in the chemical composition to 0.03 percent of C. Usually this type of stainless steel will mark with letter “L”, for example type 317L. Some types of them also have addition of Molybdenum (Mo) and Nitrogen to improve its properties. Mo is added to type 316 stainless steel to enhance the pitting and crevice corrosion resistance, besides high temperature mechanical properties (Zahida et al. 2010). Carbon is a good solid solution strengthener while nitrogen is the most effective solid solution strengthener in austenitic stainless steels. In fact, the strengthening effect of nitrogen is found to be higher than that of carbon, since nitrogen contributes to the strengthening of grain boundaries while carbon does not (Zahida et al. 2010). Type 317L that is used for material in this project is containing 18 percent of Cr, 15 percent of Ni and 4 percent of Mo.

2.2.6 Application of Stainless Steel

Stainless steels know is widely used because of its corrosion resistance and heat resistance criteria. Ferritic type 430 stainless steels usually used to such corrosives condition such as nitric acid, sulphur gases and many organic and food acids while type 405 has lower chromium and aluminium was added to prevent hardening when cooled from high temperatures, usually used for heat exchangers, heaters and combustion chambers. Martensitic type 440 stainless steels contain 17 percent Cr and 1.1 percent of C to improve toughness and corrosion resistance and typical used for instruments, bearings, races and valve parts. Austenitic type 321 have addition of titanium (Ti) element for corrosive resistance and repeated intermittent exposure to temperature above 800 degrees Fahrenheit and it is stabilized for welding, widely used in process equipment, pressure vessels and aircraft industry (William and Javad, 2006).

2.3 WELDING

2.3.1 Introduction and Basic of Welding

Welding is the most important method that is widely used in construction, fabrication, engineering and repairing fields. To weld is to join two pieces of same or different metal together (Derek, 1996). Welding is the process where two metal materials joined together with heat or pressure, with the addition of filler materials or not. Weldability of each material is different. Metals with high thermal conductivity require a high heat input and metals with refractory oxides need stronger fluxing and some materials need special treatment because they are crack sensitive (Derek, 1996). Welding will slightly transforms the microstructure at the welding spot and its surrounded area. The area is called Heat Affected Zone (HAZ).

2.3.2 Types of Welding

There are many types of welding process but generally it is divided into two main basics, that is thermal or fusion welding and welding with pressure. Arc welding, gas welding, thermit welding, electron-beam welding and electron-slag welding is classified under fusion welding. Arc welding have its own types such as metal arc welding, carbon arc welding, Tungsten Inert Gas (TIG) welding and plasma arc welding and under metal arc welding is manual metal arc, submerged arc welding and Metal Inert Gas (MIG) welding. In gas metal arc welding (GMAW), the common variations of shielding gases, power supplies and electrodes have significantly effects resulting in several different and important process variations (Behcet et al. 2005). For welding with pressure, there are resistance welding, forge welding, pressure welding and ultrasonic welding. Resistance-butt welding, flash welding, spot welding, seam welding and projection welding are classified under resistance welding (Derek, 1996). Figure 2.1 shows the illustration of MIG welding process with the nomenclature of each part.

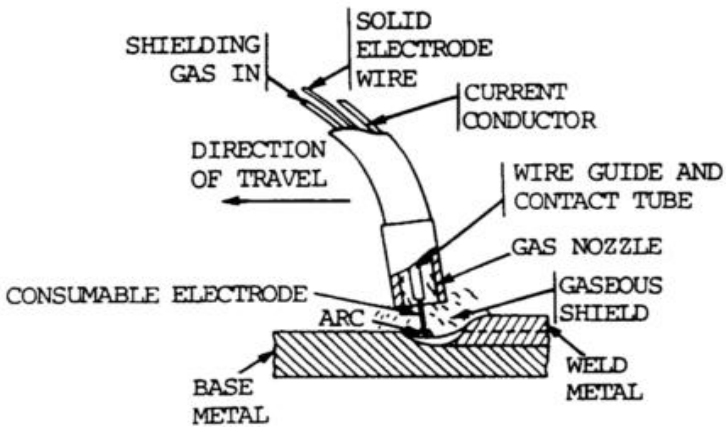

Figure 2.1: MIG welding process

Source: weldguru

2.3.3 Welding Defects and Inspection Welding

Cracks can be divided into two main classes which is hot and cold cracks. Hot cracks is happened during solidification at the time the weld is hot while cold cracks is because of excessive stress and hydrogen diffusion in steels (Girish and Pelkar, 2008). The problem on welding spot is dividing into two major, which is defect and discontinuity. A welding defect is any flaw that compromises the usefulness of the finished weldment. Discontinuity is an interruption of the typical structure of material, such as lacks of evenness in its mechanical, metallurgical or physical characteristics. Welding defects can be identified by the "naked eye". Welding defects include poor penetration. It is the failure of the welding rod and base metal to fuse together. It is caused by a root face that is too big, a root opening that is too small, an electrode that's too large, slow travel speed or a machine setting that's too low. Porosity looks "sponge like," or like tiny "bubbles" in the weld. It is caused by gases being released by the cooling weld because a current setting is too high or arc is too long. The example is as Figure 2.2. Incomplete or insufficient penetration is happened when weld metal does not extend to the required depth into the joint root. It is caused by low amperage, low preheat, tight root opening, fast travel speed and short arc length. Incomplete fusion is where the weld metal does not form a cohesive bond with the base metal. This such of defect occurs when using of low amperage during welding, electrode angles too steep, fast travel speed of welding, lack of preheat to the base metal, electrode too small, base metal does not clean well and arc off seam (Gas metal arc welding for stainless steel, 1999). The welding spot need to undergo gouging process to remove those fill weld and re weld again. Figure 2.3 is an example of incomplete fusion.

Weld spatter such in Figure 2.5 can be recognized by naked eyes by many of small spot filler weld around the weld zone likes water droplet around a glass of cold water. This spatter will form when using high arc power during welding, magnetic arc blow, incorrect setting for Gas Metal Arc Welding (GMAW) process and using the damp electrodes. Undercutting is a problem that causes welding defects. It burns away the base metal at the toe of the weld. It is caused by a current adjustment that is too high, an arc gap that is too long or failure to fill up the crater completely with weld metal. Figure 2.4 giving some views about the undercut defect.

Figure 2.2: Porosity in welding

Source: Wanda

Figure 2.3: Incomplete fusion

Source: Wanda

(a) (b)

Figure 2.4: (a) Illustration of undercut. (b) Example of undercut on welding

Source: Wanda

Figure 2.5: Weld spatter at the weld zone

Source: Wanda

2.4 ELECTRIC DISCHARGE MACHINING (EDM)

EDM wire cut is an electro thermal production process that used electric discharge or sparks to cut materials like metals and steels. It is using a thin single-strand metal wire such as brass in conjunction with de-ionized water for purpose of conducting electricity to produce the sparks (Edm, undated). However, it is critical when cutting through the weldment because of welding process that formed the stronger and new grain structure at the weldment. Cutting process at the rough welded area is very tough and need to consider vibration factor (Romlay and Mokhtar, 2007). The curves path that to be cut is also critical. There is some limitation of cutting speed in order to reduce errors during cutting at the curving zone (Sanchez et al. 2007).

2.5 MECHANICAL TESTING

2.5.1 Introduction of Mechanical Testing

Mechanical testing is a way to test the mechanical properties of a material. Some of mechanical properties that is under consideration is yield strength, tensile strength, compression, elongation after rupture, constriction, hardness, impact value, torsion and bending strength. The concept is some specimen will be taken from a material to be test under a specific test with a specific calibrated test machine. There is many types of mechanical testing such as tensile test, hardness test, bending test, torsion test, impact test, creep test, fatigue test, and compression test.

2.5.2 Tensile Test Principles and Parameters

The tensile test is a test to analyze the yield strength, Ultimate Tensile Test (UTS) and strain of a material. It is involving the elastic and plastic deformation of the material when the material undergo tension force in uniaxial in constant rate. The mechanical properties of metals and alloys that are of engineering importance for structural design and can be obtained from engineering tensile test are:

- Modulus of elasticity
- Yield strength at 0.2% offset
- Ultimate tensile strength
- Percent elongation at fracture
- Percent reduction in area at fracture

The test usually will be run at room temperature. Because there is no definite point on the stress-strain curve where elastic strain end and plastic strain begins, the yield strength is chosen to be that strength when a definite amount of plastic strain occurred (William and Javad, 2006). Modulus of elasticity is depend on the bonding strength between atoms in a metal or alloys. Generally, the maximum elastic deformation for metal is 0.5% or less. In tensile test, samples develop quickly fracture by localized deformation in the neck, inhibiting the formation of shear bands (Wang and Ma, 2004).

2.5.3 Tensile Test Machines and Specimens

Universal tester is the common test machine that can provide tension, compression and bending test. Electromechanical machines are based on a variable speed-speed electric motor, a gear reduction system, and one, two or four screws that move the crosshead up or down. This motion loads the specimen in tension and compression (ASM, 2010). It consists of three main components, which are Load Frame; ServoHydraulic Control Systems and Hydraulic Power Pack. The load cell capacity is approximately 100kN for dynamic and 120kN for static loading. The actuator capacity is 100kN for dynamic with 75mm stroke. Maximum pressure or force can be applied is 21 MPa and specimen thickness availability is 0 to 7.8 mm flat plate (Manan, 2000).

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A standard specimen is prepared in a round or a square section along the gauge length, depending on the standard used. Both ends of the specimens should have sufficient length and a surface condition such that they are firmly gripped during testing. A tensile specimen is a standardized sample cross-section. It has two shoulders and a gauge section in between. The shoulders are large so they can be readily gripped, whereas the gauge section has a smaller cross-section so that the deformation and failure can occur in this area (David, 2004). The shoulders of the test specimen can be manufactured in various ways to mate to various grips in the testing machine (see the image below). Each system has advantages and disadvantages; for example, shoulders designed for serrated grips are easy and cheap to manufacture, but the alignment of the specimen is dependent on the skill of the technician. On the other hand, a pinned grip assures good alignment. Threaded shoulders and grips also assure good alignment, but the technician must know to thread each shoulder into the grip at least one diameter's length, otherwise the threads can strip before the specimen fractures (David, 2004). By referring to the Figure 2.6, Grip A is for threaded shoulder for use with a threaded grip.

Grip B is for round shoulder for use with serrated grips. Grip C is a butt end shoulder for use with a split collar. Grip D is a flat shoulder for used with serrated grips. Grip E is a flat shoulder with a through hole for a pinned grip. Figure 2.7 shows the nomenclature of the specimen.

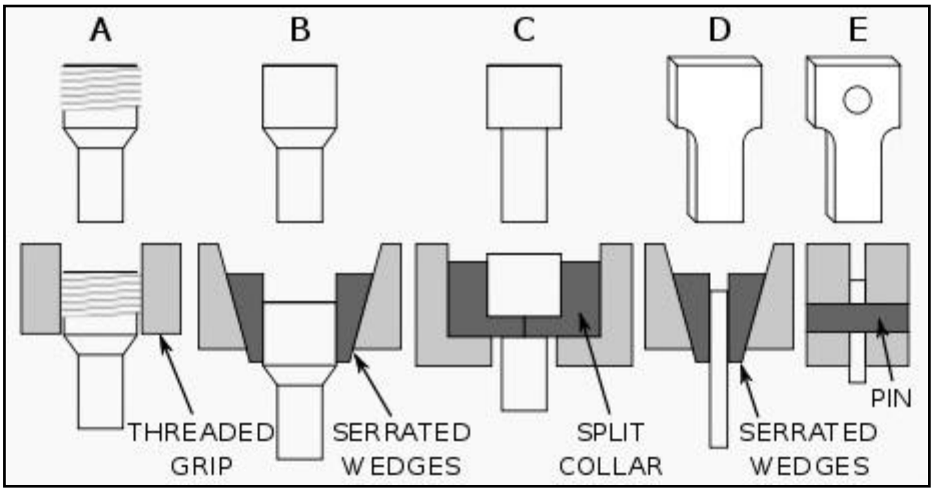


Figure 2.6: Specimen grip for tensile test.

Source: David, 2004

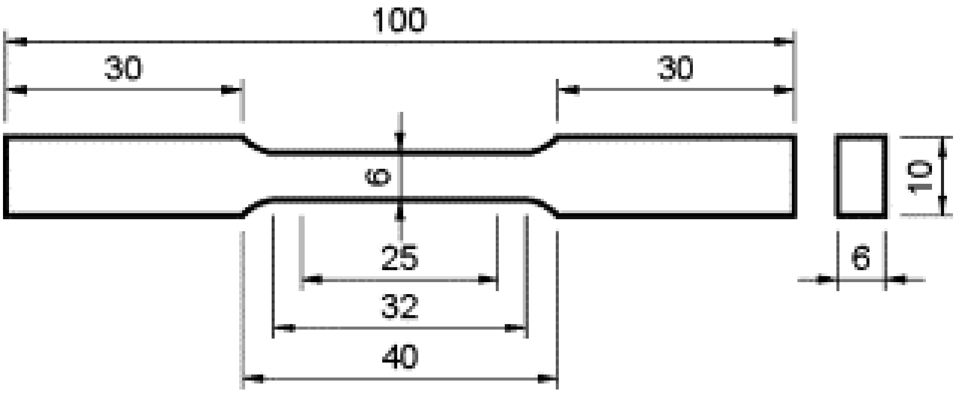


Figure 2.7: Specimen for subsize nomenclature based on ASTM E-8

Source: ASTM E-8 2008

2.5.4 Stress-Strain Curve

Engineering stress on the bar is equal to the average uniaxial tensile force on the bar divided by original cross sectional area of the bar (William and Javad, 2006). During testing of a material sample, the stress–strain curve is a graphical representation of the relationship between true stress, derived from measuring the load applied on the sample, and strain, derived from measuring the deformation or elongation of the sample, such as elongation, compression, or distortion. The slope of stress-strain curve at any point is called the tangent modulus; the slope of the elastic (linear) portion of the curve is a property used to characterize materials and is known as the Young's modulus. The area under the elastic portion of the curve is known as the modulus of resilience. The nature of the curve varies from material to material. The following diagrams illustrate the stress–strain behaviour of typical materials in terms of the engineering stress and engineering strain where the stress and strain are calculated based on the original dimensions of the sample and not the instantaneous values.

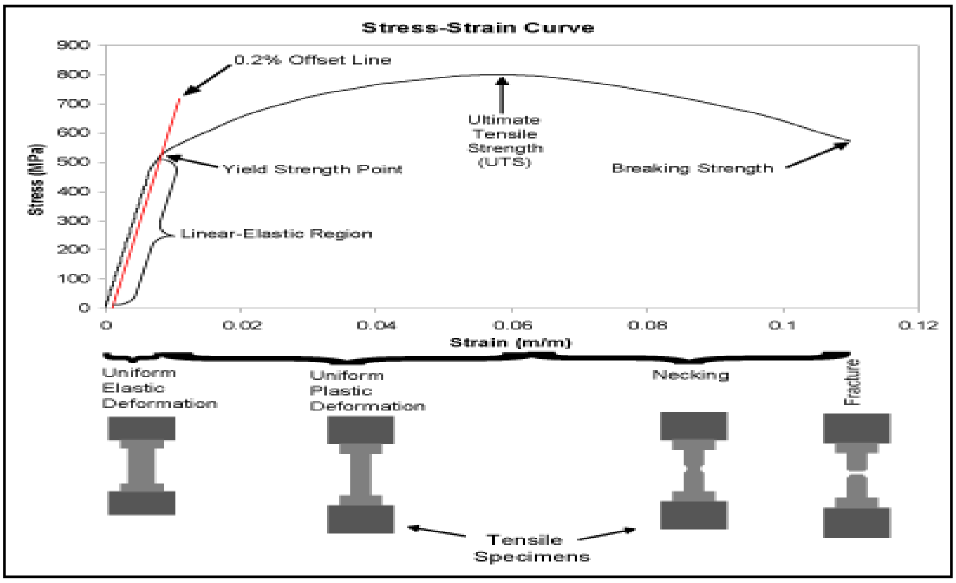


Figure 2.8: Illustration shows the failure process of a specimen with respect to the stress strain curve.

Source: Ndt resources centre

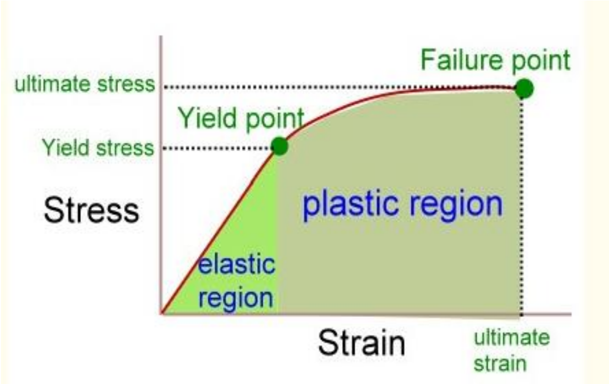


Figure 2.9: Illustration of plastic and elastic region

Source: Huei Meng Chai

2.5 ACOUSTIC EMISSION

2.5.1 Introduction of Acoustic Emission

Acoustic Emission (AE) refers to the generation of transient elastic waves produced by a sudden redistribution of stress in a material. AE from transient elastic waves generated within a material owing to sudden localized irreversible microstructural changes yields deformation on dynamic involved in plastic deformation, crack initiation and propagation (Miller et al. 2005). Sources of AE vary from natural events like earthquakes and rockbursts to the initiation and growth of cracks, slip and dislocation movements, melting, twinning, and phase transformations in metals..Detection and analysis of AE signals can supply valuable information regarding the origin and importance of a discontinuity in a material. Because of the versatility of Acoustic Emission Testing (AET), it has many industrial applications (e.g. assessing structural integrity, detecting flaws, testing for leaks, or monitoring weld quality) and is used extensively as a research tool. Acoustic Emission is unlike most other nondestructive testing (NDT) techniques in two regards. The first difference pertains to the origin of the signal. Instead of supplying energy to the object under examination, AET simply listens for the energy released by the object. AE tests are often performed on structures while in operation, as this provides adequate loading for propagating defects and triggering acoustic emissions. The second difference is that AET deals with dynamic processes, or changes, in a material. This is particularly meaningful because only active features (e.g. crack growth) are highlighted. The ability to discern between developing and stagnant defects is significant. However, it is possible for flaws to go undetected altogether if the loading is not high enough to cause an acoustic event. Furthermore, AE testing usually provides an immediate indication relating to the strength or risk of failure of a component. Other advantages of AET include fast and complete volumetric inspection using multiple sensors, permanent sensor mounting for process control, and no need to disassemble and clean a specimen.

2.5.2 Acoustic Emission Principles and Sources

The most detectible acoustic emissions take place when a loaded material undergoes plastic deformation or when a material is loaded at or near its yield stress. On the microscopic level, as plastic deformation occurs, atomic planes slip past each other through the movement of dislocations (WavesinSolids LCC, 2009). These atomic-scale deformations release energy in the form of elastic waves which “can be thought of as naturally generated ultrasound” traveling through the object. When cracks exist in a metal, the stress levels present in front of the crack tip can be several times higher than the surrounding area. Therefore, AE activity will also be observed when the material ahead of the crack tip undergoes plastic deformation (micro-yielding). Figure 2.10 shows the example of AE waveform.

Two sources of fatigue cracks also cause AE’s. The first source is emissive particles (e.g. nonmetallic inclusions) at the origin of the crack tip. The second source is the propagation of the crack tip that occurs through the movement of dislocations and small-scale cleavage produced by triaxial stresses (NDT Resource Centre, 2011). Figure 2.11 (a) gives the better understanding to AE properties. The amount of energy released by an acoustic emission and the amplitude of the waveform are related to the magnitude and velocity of the source event. Analysis of these signals yield valuable information regarding the origin and importance of a discontinuity in a material. Figure 2.11 (b) shows area under graph with corresponding to the amount of energy.

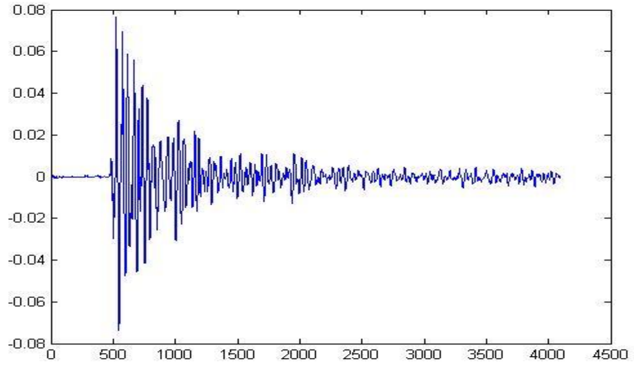
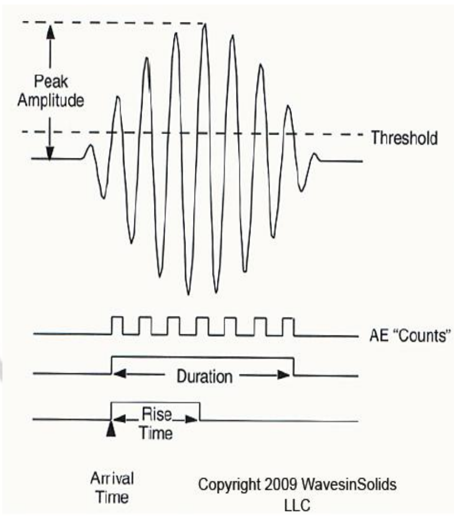


Figure 2.10 : Example of AE waveform

Source : WavesinSolids LCC, 2009



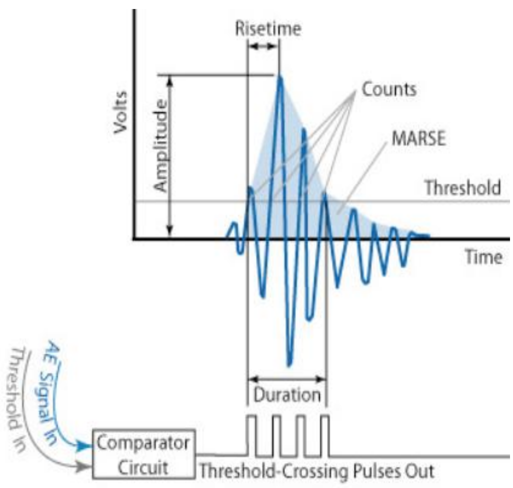


Figure 2.11 (a)

Figure 2.11 (b)

Figure 2.11 : (a) AE properties for count and duration (b). AE properties for energy

Source : WavesinSolids LLC, 2009

2.5.3 Acoustic Emission Sensors and Transducers

Acoustic emission testing can be performed in the field with portable instruments or in a stationary laboratory setting. Typically, systems contain a sensor, preamplifier, filter, and amplifier, along with measurement, display, and storage equipment (e.g. oscilloscopes, voltmeters, and personal computers). Acoustic emission sensors respond to dynamic motion that is caused by an AE event. This is achieved through transducers which convert mechanical movement into an electrical voltage signal. The transducer element in an AE sensor is almost always a piezoelectric crystal, which is commonly made from a ceramic such as lead zirconate titanate (PZT). Transducers are selected based on operating frequency, sensitivity and environmental characteristics, and grouped into two classes which is resonant and broadband. The elimination of separate amplifiers, cables and vulnerable connectors improves greatly the reliability in tough environments and significantly reduces set up time (Physical Acoustic Corporation, 2010). The majority of AE equipment is responsive to movement in its typical operating frequency range of 30 kHz to 1 MHz. For materials with high attenuation such as plastic composites, lower frequencies may be used to better determine AE signals. The opposite holds true as well.

2.6 REVIEWS ON RELATED RESEARCH

Recent paper is discussing about the monitoring by using acoustic emission on slow strain rate tensile test of 304L stainless steel in supercritical environment. As a a result, in situ acoustic emission is suitable and have high capability to work as monitoring method. The supercritical water environment (250 bar, 550°C) significantly decreases the strains to failure in comparison to the test in 550°C in air. High AE activity during earlier of plastic deformation and at the end of the test, when cracking occurred. During pre-plastic range, AE activity is caused by microyielding. Burst of signals in shorttimes where occurred during the crack tips start to move. The parameters that is the best in distinguish between dislocation and cracking signals is by using duration and risetime. Amplitude and energy is not significant for clustering in this studies (Mathis et al. 2011).

Recent paper is focussing to the analysis on acoustic emission to the Titanium (Ti) composite material in the conventional tensile test procedures in air. Based on the result, The composites used as the material is 1140+/Ti-6-4 and SCS-6/Ti-ß21s composites. AE activity is found in many of high energy at a range of increasing in stress in SCS-6/Ti-ß21s due to debonding starting at load of 5 MPa and it is incrementing through the process. AE energy is in peak for SCS-6/Ti-ß21s composites, approximately 4 times more than the 1140+/Ti-6-4 composites. Burst of AE signals is detected within range of 300 to 420 MPa. The cracking of outermost carbon coating and the reaction zone in 1140+/Ti-6-4 and to cracking of reaction zone in SCS-6/Ti-ß21s also had been detected (Wu et al. 2001)

Recent paper had made some experimentation about the effect of notched and unnotched specimen to the AE signals during the tensile test. The material used is nuclear grade AISI type 304 stainless steel. The experiment is to make comparative analysis of AE activity from notched and unnotched with varying of notched length. Cross sectional area of the notched is used to calculate the Yield strength (YS) and Ultimate Tensile strength (UTS) and during the tensile test, YS and UTS is increased and ductility decreased in increasing of notched length. The AE total counts get from the experiment had been analyzed with respect to the stress intensity factor and the size of plastic zone based to the yield load. As a result, prior to and during yielding, notched specimen having higher AE activity compares to the unnotched specimen. Beyond yielding or elastic deformation, AE activity on both specimens is reduces. The higher activity of AE also observed from before and during tearing of notched specimen compares during at necking elongation of unnotched specimen (Mukhopadhay et al.1998).

Tailor welded blank (TWB) steels is widely used in automotive and a set experiment were conducted to measure the deformation of properties of laser weld in TWB steel using tensile test. The weld metal properties are determined by using a “ rule of mixtures “ type of calculation. The 0.9 mm specimen was welded parallel to the rolling direction and the other of 2.7 mm specimen was welded perpendicular to the rolling direction. The base metal is provided to compare the difference between base and welded metal. Based on the strain, the difference between average stress for welded and base metal specimen is increased by the decreasing of specimen size. One of the factor that resulted to the measured of strength is the gage length. Thinner gage length will give higher measured strength (Abdullah et al. 2000).

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

The scope of this chapter is to explain by details the method and ways on how to run this project to get the data and to analyze it to know the signal characteristics based on each of specimen. The specimen will be prepared in a number of four. Each specimen has their own condition. First and second specimens is base metal, other specimens is having weldment on the specimen that have their own defects and quality of welding. The size and dimensions of the specimen is by following the ASTM E-8.

The tensile test machine will be used to apply axial stress loading to the specimen in a slow rate. The crack activity will be looked in detail by using acoustic emission (AE) signal. This is the critical things to do because it will emit signal when energy is emit in the structure by dislocation or movement of the microstructure.

Then the data will be interpret by using graphical method to see the characteristics of signal parameters based on four region that is elastic, elastic-plastic, plastic and broken phases.

3.2 FLOW CHART

Figure 3.1 as shown is the project flow chart from start until this thesis have been checked and submitted to the university. It is illustrated the process or the making of this project and the report.

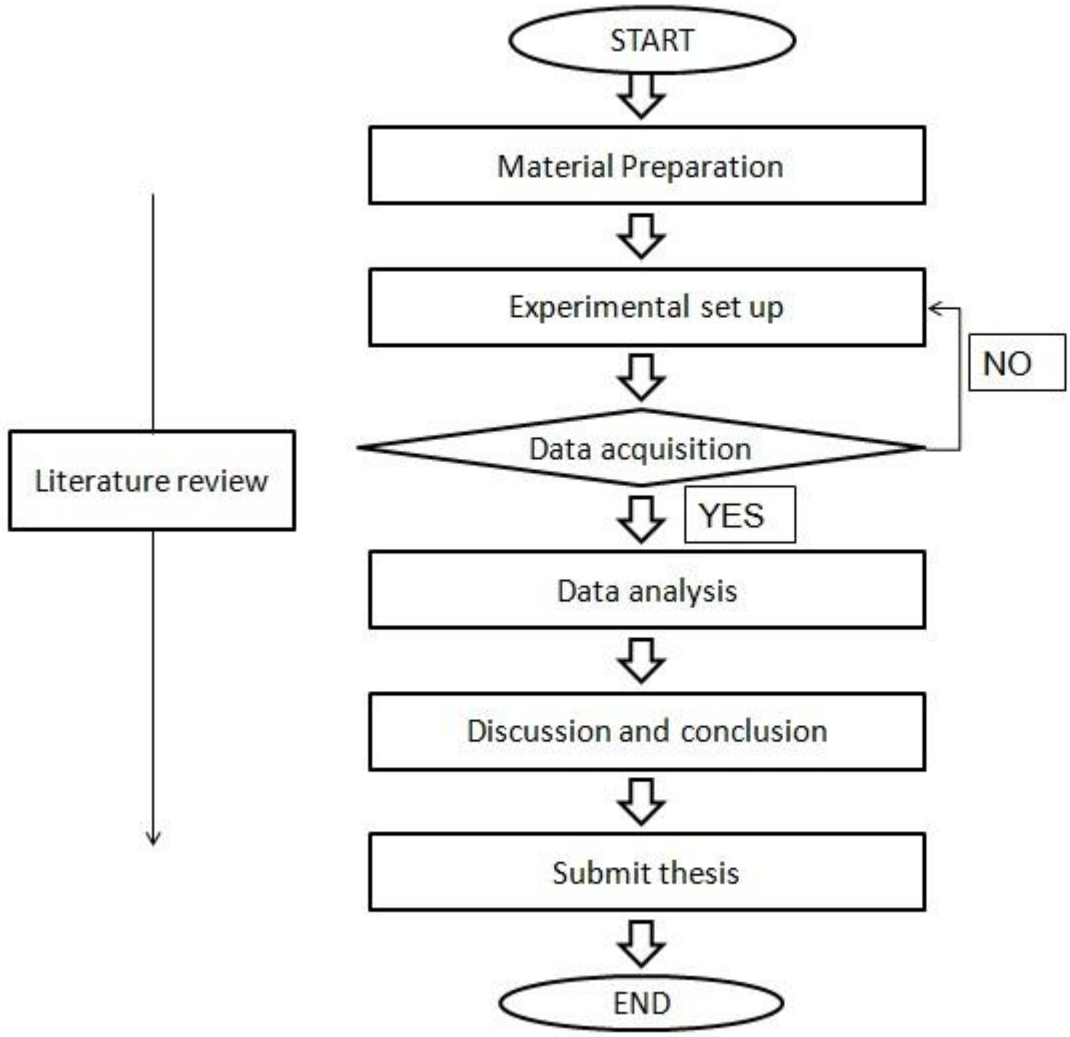


Figure 3.1: Project flow chart

3.3 SPECIMEN PREPARATION

The material used for this project is type 317L Stainless Steel. It is widely used in industry as the main materials to make pressure vessel (William and Javad, 2006). This project requires of two set of specimens and one set is consists of one specimen which is taken as base metal. Another set having three specimens with their own defects of welding.

3.3.1 Bendsaw

The 6 mm plate with dimension of 300 mm width and 270 mm length is cut to two with each part having 300 mm width and 135 mm length. A part from those two parts then is cut into two for preparing the welding specimens. Table 3.1 shows the parameter used to cut the material.

Table 3.1: Parameters used to cut the 317L stainless steel

Parameters	**Value**
Pressure applied	0.5 Bar
Hardeness	9
Width of cutter	1 mm

3.3.2 Welding

3.3.2.1 Preparation for Welding

The material that had been cut into two is prepared for welding process. V-groove at one side of each material is being made to do the single V type of joint. Figure 3.2 shows the bevel angle and root gap by illustration. The nomenclature for the groove is as stated in Table 3.2. The material that had been finished doing groove is as shown in Figure 3.3.

Table 3.2: Nomenclature of V-groove

Nomenclature	**Values**
Root gap	1 mm
Bevel angle	32 °
Root face	2 mm
Included angle	64°

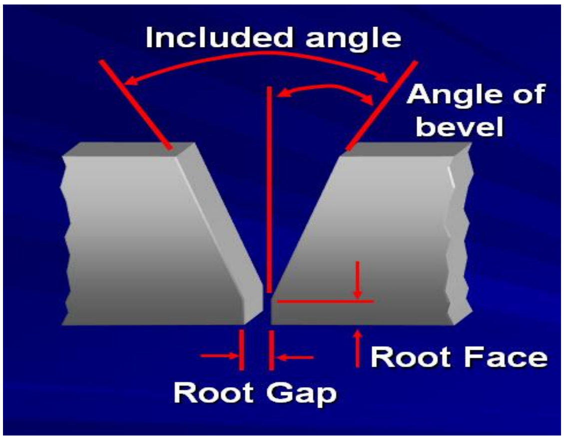


Figure 3.2: V-groove nomenclature

Source: Welding handbook by MMHE

Figure 3.3: Material finished making v-groove

3.3.3.2 MIG Welding

MIG welding is a type of GMAW called Metal Inert Gas (MIG). It is using filler wire and gas to weld the material. The filler that had been used is 304L stainless steel with diameter of 1 mm and by using Carbon Dioxide (CO_2) gas. The parameter of welding is as stated in Table 3.3.

Table 3.3: Parameters of welding by its layer

Parameters	Layer 1	Layer 2
Voltage (V)	15	20
Wire speed (mm/min)	89	115

3.3.3 EDM Wirecut

Electric Discharge Machining (EDM) wire cut were being used to cut the material into required dimension as stated in ASTM E-8. But before that, the material was cut into three pieces by using bendsaw with the width of 20 mm each and using previous parameters in bendsaw section. The parameters of using EDM wire cut is as stated in Table 3.4.

Table 3.4: Parameters for cutting stainless steel

Parameters	Value
WS	050 mm/ min
WP	045
WT	060
ONSET	006
SF	008/005

3.3.4 Milling

Wire cut is hard to cut the welded specimens, hence wire cut just used to make the curving at each specimens of welded. The welded area is left for milling. The spindle speed used for milling is 900 rpm. The value of cutting speed for stainless steel is 200 feet per minute (fpm). Depth of cut used is 0.5 mm per cycle. Equation 3.1 below shows the relationship of cutting speed and cutter diameter to the spindle speed.

$$\text{Spindle speed (RPM)} = \frac{Cutting\ speed\ x\ 1000}{pi\ x\ cutter\ diameter\ (mm)} \tag{3.1}$$

3.3.5 Optical Measurement

This machine as in Figure 3.4 is used to take picture of the specimens and its defects and also to measure the size of cracks or holes on the welded specimens. It can zoom or focus on an image until four times of zoom. It is just suitable to see the surface condition of a specimen.

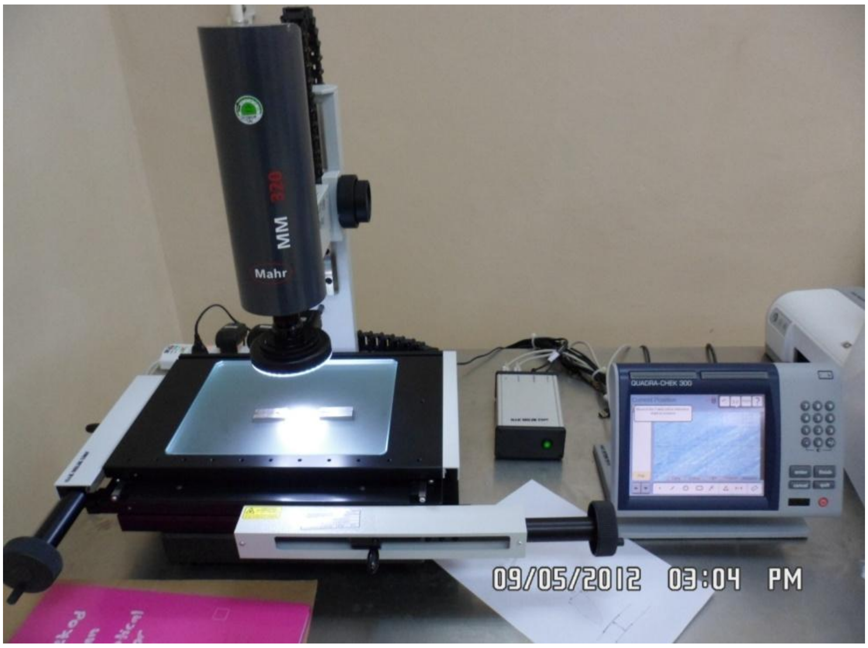


Figure 3.4 : Optical measurement machine

3.4 TENSILE TEST

The dimension of those specimens is by referring to the ASTM standard. Hence, the section E-8 in ASTM standard will be used as reference to prepare the specimens. This project will precede the test with rectangular tensile test specimen based on plate type. This specimen will be follow to the standard specimen that is subsize type, 6 mm of thickness. Table 3.5 shows the detail dimension of the tensile specimens with extension to the grip length and wide to fix with the size of AE sensor.

TABLE 3.5: Detail dimension of rectangular tensile test specimen

No	Nomenclature	Dimension (mm)
1	G- Gage length	25 ± 0.1
2	W- Width	1.000 ± 0.003
3	T- Thickness	6± 0.1
4	R- Radius	6
5	L- Overall length	132 ± 0.2
6	A-Length of reduced section, min	32
7	B- Length of grip section	44.09
8	C- Width of grip section, approximate	20

3. 5 EXPERIMENT SETUP

3.5.1 Pencil Break Test Procedures

Pencil break test is one of the calibration procedures before using the AE piezoelectric sensor. It is used to identify noise for the experiment and to set the suitable threshold and filter corresponding to the noise and other acoustic sources. Figure 3.5 shows the AE piezoelectric sensor that is used in this experiment.

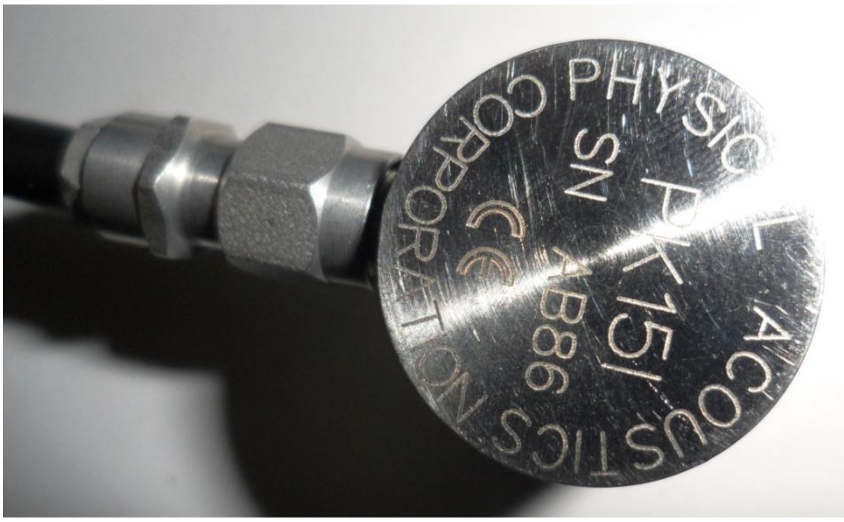


Figure 3.5: AE sensor PK 151

The AE piezoelectric sensor is attached to the specimen at the grip area with selofone tape and grease. The connections of AE sensor to Data Acquisition (DAQ) and

DAQ to laptop need to be connected. AEwin software should be standby with acquire mode. After that, the pencil lead is pressed to the specimen until its fracture. Then, he signals from the pencil break are captured and make sure that there is no noise appeared. The acquired data is save in file by selecting `ASCII waveform` and the steps is repeated for 3 times of pencil break test.

3.5.2 Tensile Test Procedures

The machine used for tensile test is Instron with capability to 50 kN applied load. ASTM standard for tensile loading of steels is ASTM E8M. The machine is for compression and tension test. The different for those test method is just the grips used.

Firstly, the Instron machine is on and BLUEHILL software is selected. The specimen is being grip by using frictional grips and icon METHOD is selected. Then the length, thickness and width of the specimen is determined in the software. The crosshead speed used for the test is 1 mm/min. TEST icon is selected and the test method which is tension test had been determined. After that, the data for being plot such as tension load, tensile strength and strain is selected and the method is being save. The load is set to zero by clicking on `Balance all`, then the START icon is clicked to start the test. After the specimen is fractured, UTILITIES icon is clicked and the result is saved. Figure 3.6 shows the set up of experiment before conducting the tensile test.

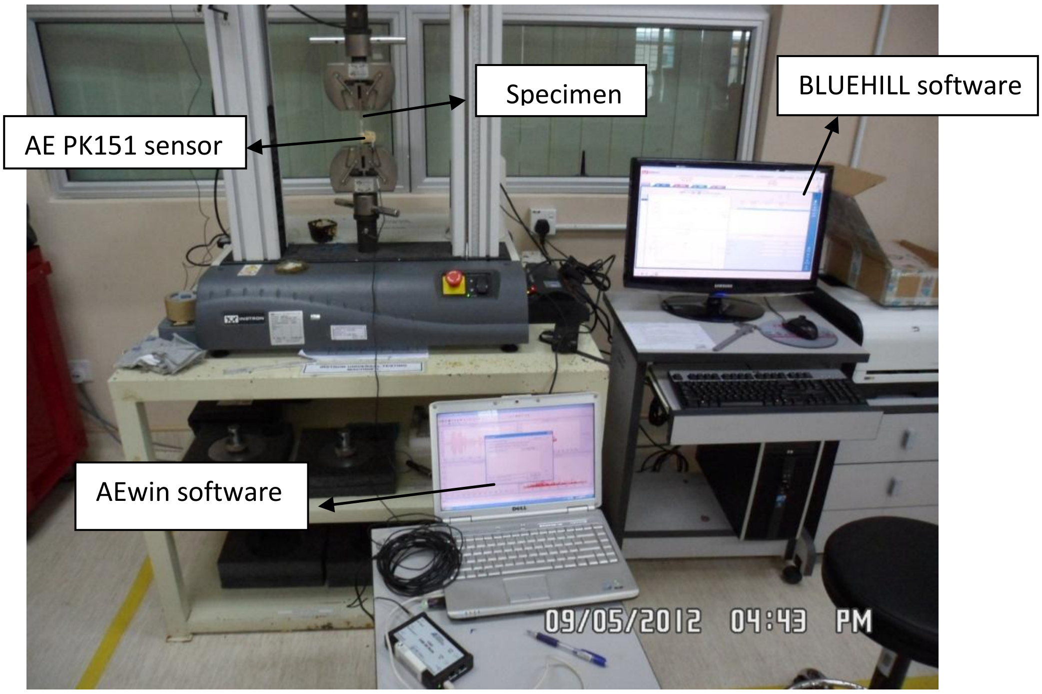


Figure 3.6: Tensile test set up

3.5.3 Acoustic Emission Data Acquisition

The AE transducer is put on the specimen. Enter the AEwin software in the computer and make Layout (.LAY). The parameter such as AE channel, threshold, analog filter, sample rate, pre-trigger and hit length value is set up in "AE hardware set up". Parameter such as hits, counts, RMS and energy was set up in "Graph set up". The "Acquire" and "start" icon is clicked. The sensor is ready for collecting data from tensile test. After finished, the icon "utilization" is clicked. The raw data is save in a folder after icon "ASCII Waveforms" is clicked. The steps were repeated for each and other specimen.

3.6 DATA ANALYSIS

After the tensile test and the AE signals were captured, all the raw data is saved to the excel format. The AE properties that had been selected for further analysis is RMS, count and energy. This data were prepared for the analysis and selection of data. All the AE data will be selected with some characteristics about 50 data. Then the waveform for each data is compared to choose the uniform shapes of waveform. Then, 30 data will be selected to be put in stress and AE properties versus time graph. Figure 3.7 shows the steps of data selection from raw data to the final 30 data.

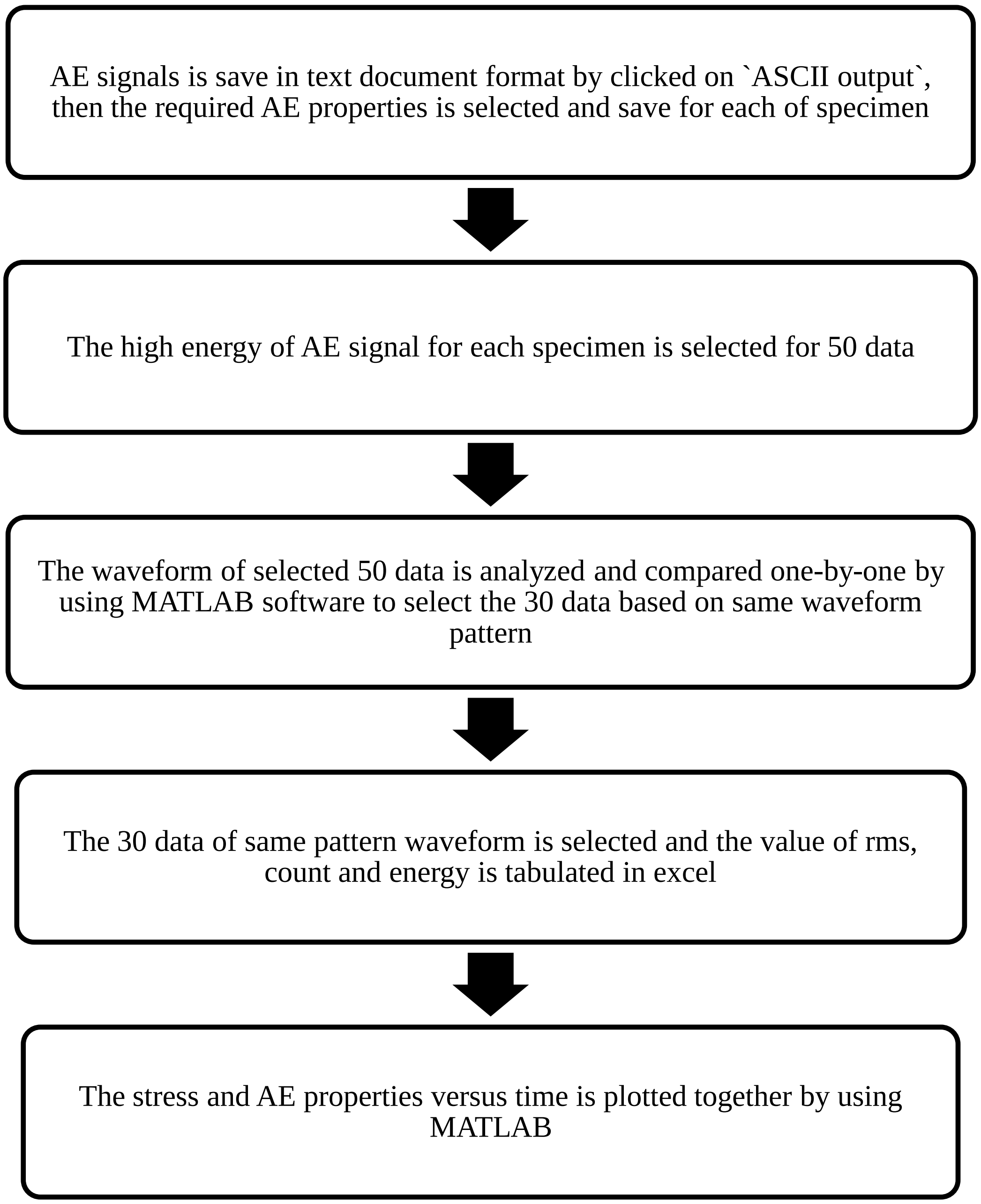


Figure 3.7: Steps of data selection

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

The objectives of this project are to acquire AE data from the tensile test and also to analyze the AE properties and find the correlation to the stress-strain curve. There are 2 sets of specimens. The first set is one specimen that is base metal. Second set is having three welded specimens with different defects. The AE properties that is focussing on is Root Mean Square (RMS), energy and count for each specimen. This properties was picked based on the waveforms and values of energy. The sets of data were plotted in stress versus time graph. Each of specimens will have its graph and discussion were explained the fracture and the signals that is emitted. Figure 4.2, 4.3 and 4.4 shows the defects or cracks on the welding specimen that will affect the AE signals captured and its tensile strength value.

4.2 CONDITION OF SPECIMENS

The base metal shown as in Figure 4.1 was cut by using EDM wirecut. Base metal worked as the references to compare the AE activity between normal surface and welded with defected on the surface of specimens.

Figure 4.1: Base metal specimen

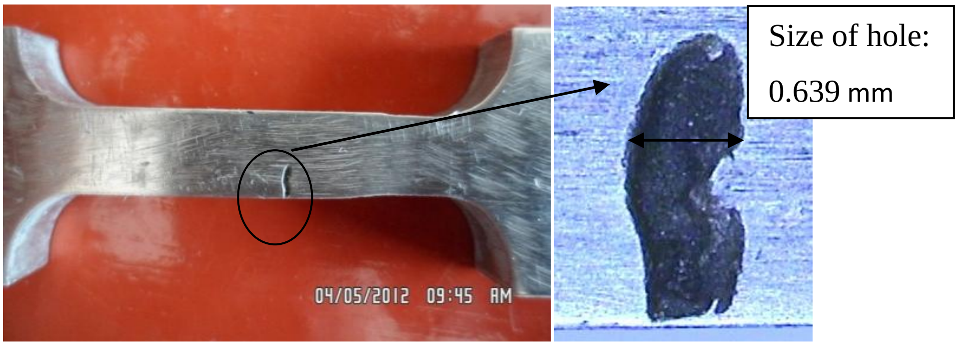


Figure 4.2: Defect on welding for specimen 1 for 0.7 times of zoom

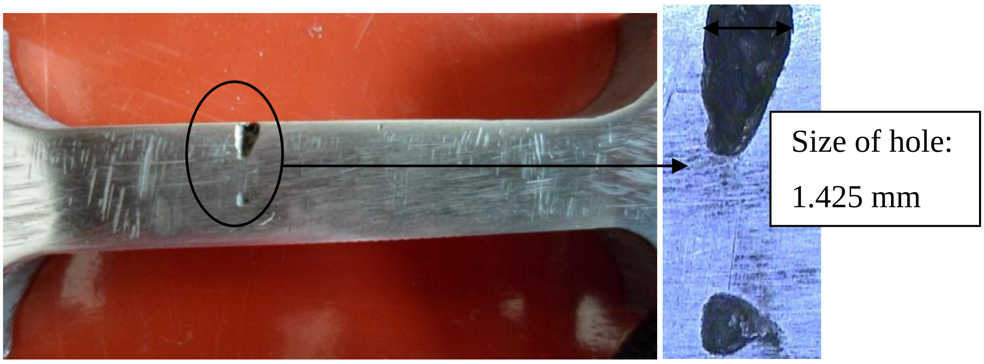


Figure 4.3: Welding specimen 2 and its defect for 0.7 times of zoom

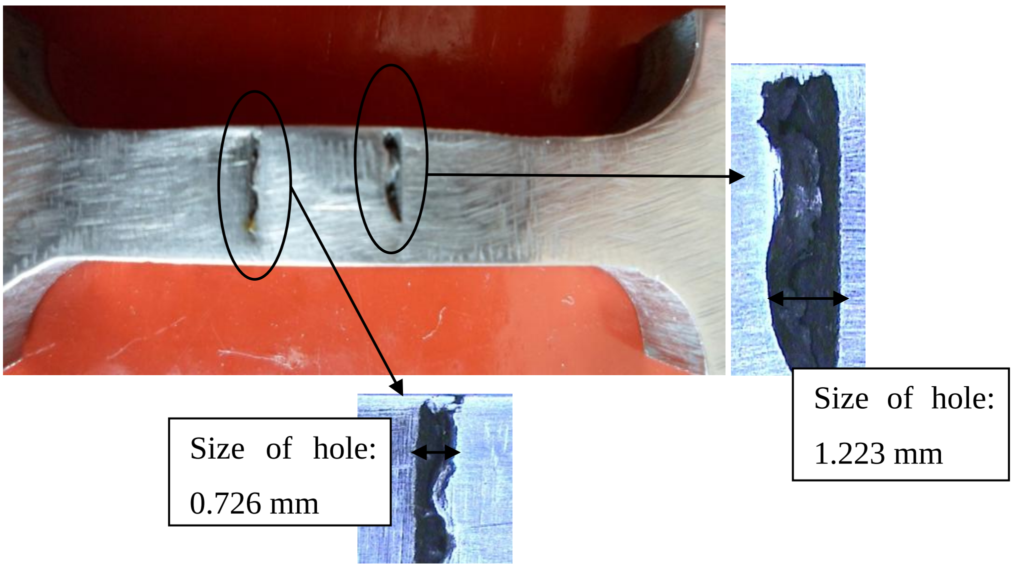


Figure 4.4: The defects on welding specimen 3

4.3 TENSILE TESTING

Figure 4.5 shows that the tensile load for specimen 1 while figure 4.6 (a), 4.6 (b) and 4.7 shows the tensile graph for weld specimen. Even though the material is same and the strain rate is same that is 1 mm/min, but because of the welded factor make the value is different. Table 4.1 shows the different in value based on each specimen. Crack at the welded material significantly gives effect to the stress-strain graph of material 317L stainless steel.

Base metal is used as reference to differentiate the tensile result and AE signals captured form the test on welded specimens. Based on the test that was conducted, the tensile stress for base metal is 632 MPa. This value is higher compared to those welded specimens because of there is no defects or flaws on the specimen.

The AE signals were occurred more during elastic region and broken region and reduce at plastic region. The energy release from the base metal is lower than welded specimens because of there is no flaws. Hence the structure is in strength without no tendency to failure and less of slips and dislocation of the structure. Less AE signals captured during plastic region or yielding with the increasing of nominal strain. The stress contribution along the specimen is uniform, so less high energy release because of the dislocation. The fractures also having some criteria like ductile fracture.

For a nuclear grade stainless steels, there is two sources of AE that had been identified, it is by dislocation activity of the structure and by deformation-induced martensitic deformation. Deformation-induced is having two types, a) strain-induced martensitic deformation, b) stress-induced martensitic deformation (Mukhopadhay et al. 2007). The source of AE signals emitted from the base metal is in the progressive yielding region, that is to be considered to originate from strain-induced martensitic deformation (Mukhopadhay et al.1993).

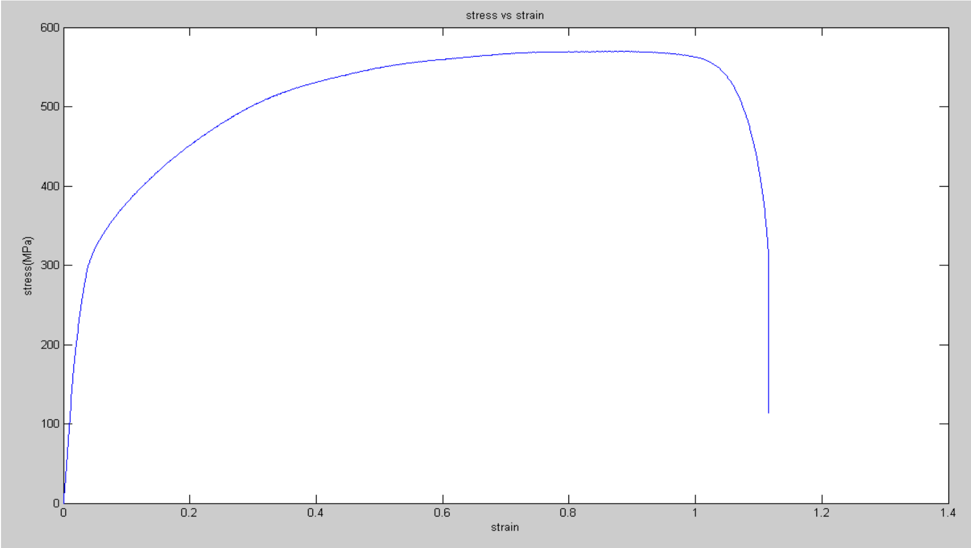
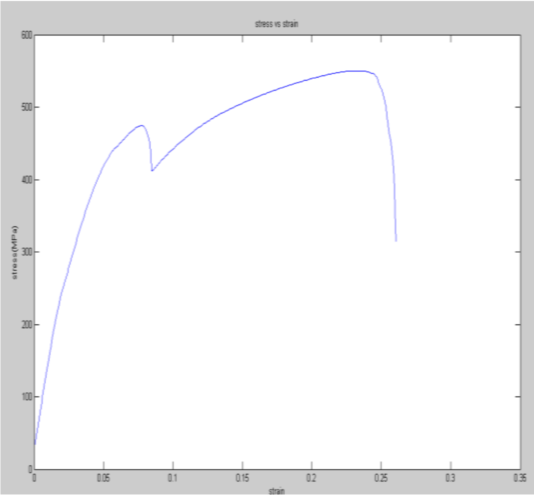
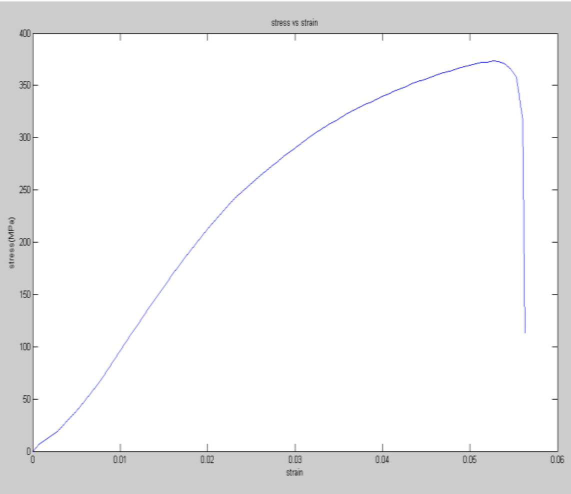


Figure 4.5: Stress-strain curve for base metal





(a) (b)

Figure 4.6: (a) Stress-strain curve for welded specimen number 1 (b) Stress-strain curve for welded specimen

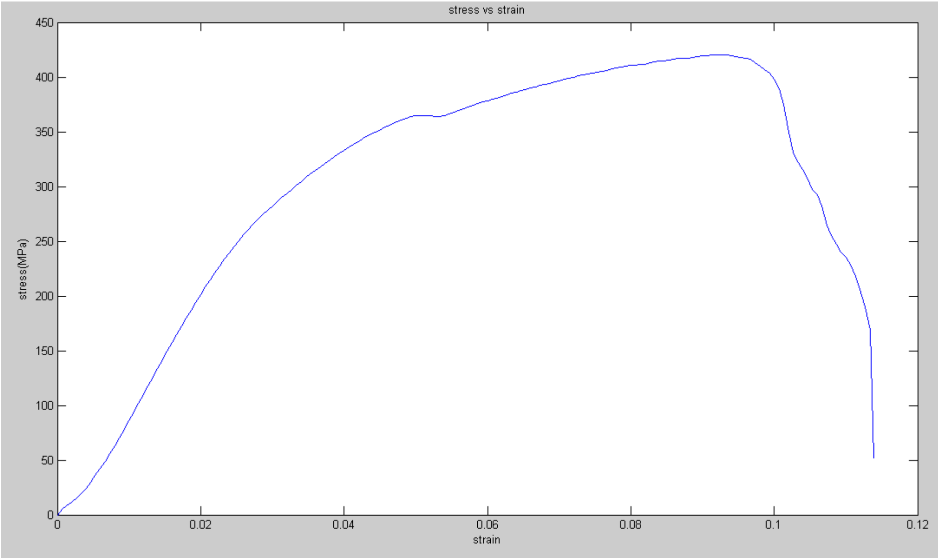


Figure 4.7: Stress-strain curve for welded specimen number 3

Table 4.1: Maximum load and tensile stress for each specimen

Number of specimen	Maximum load (N)	Tensile stress at tensile strength (MPa)
1	20509.50	631.52405
2	19786.30	409.82397
3	13442.09	278.65021
4	15122.33	299.40756

4.4 CORRELATION BETWEEN THE STRESS-STRAIN CURVE WITH AE PROPERTIES

In order to achieve the objectives of this project, the graph of load versus time is needed to be constructed. It is because the AE properties is by respecting to the time. The AE properties that will be analyzed is RMS, energy and count for each specimen. After that, discussion about the fracture and emitted AE signals will be discussed.

Figure 4.8 shows the energy emitted from the tensile test with respected to the time. The highest energy value is 154 at 39.3 second. Highest energy emitted before the tensile strength during elastic region. More frequent of AE signals emitted during elastic region compared to the elastic region is captured in the graph.

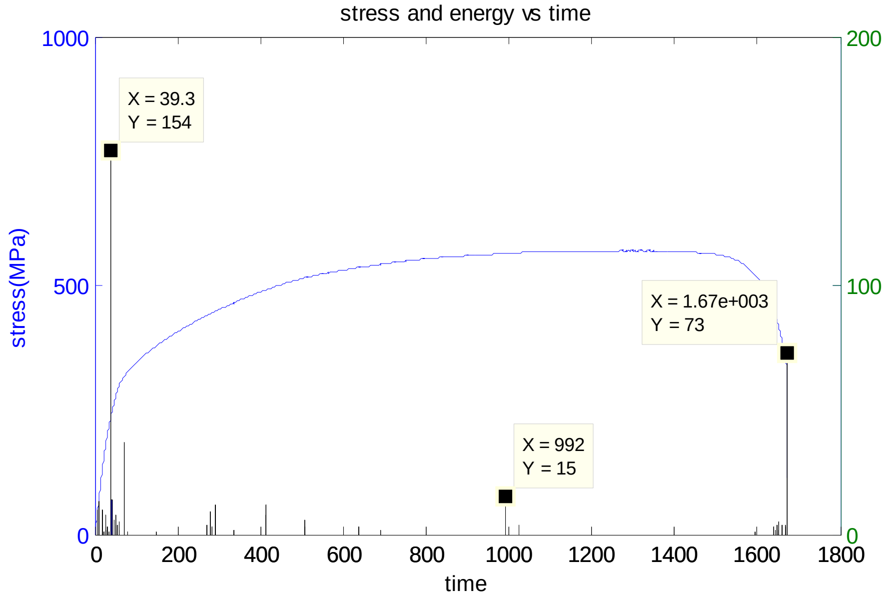


Figure 4.8: Stress and energy versus time for base metal

Figure 4.9 (a) shows the count captured from the tensile test taken from the AEwin software. Value of count is highest also during in elastic region with 159 at 39.3 second. It is also the highest signal energy and it shows the huge movements or stress distribution acting during that period of time. Figure 4.9 (b) shows the RMS value taken from AEwin software during tensile test. The bar is the RMS value and the line is for stress versus time graph. Highest value of RMS is captured on 39.3 second with value of 8.4 mV. Many of the RMS value is from 0.4 mV to 1.2 mV.

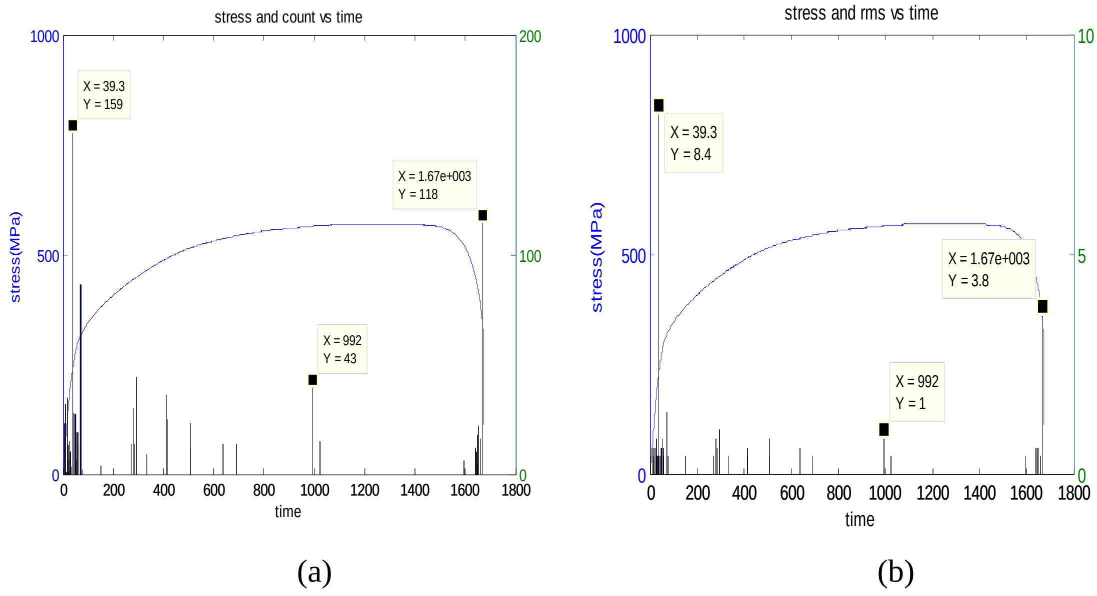


Figure 4.9: (a) Stress and count versus time for base metal, (b) Stress and RMS versus time for base metal

Figure 4.10 shows the energy distribution with respected to the time. The energy is greater in its intensity compared to base metal and elastic region have higher hits data. Highest value of energy is 540 at a time of 85.8 second. Lower energy captured during elastic region but higher energy captured during plastic region and after yielding.

Figure 4.11(a) shows the count distribution with respected to the time. The distribution of count can easily see here and the largest value is 214 at a time of 85.8 second. Highest energy produced a highest value of count. More hits were captured before yielding and less hits captured during plastic region. Figure 4.11(b) above shows the RMS value in terms of bars with respected to the time. Frequently higher value of rms captured during elastic region. Highest value of RMS is 36.6 mV at 52.5 second. The highest energy and count have lower RMS that is 29 mV at 35.8 second. Mostly the value of RMS in elastic region is lower than in plastic region.

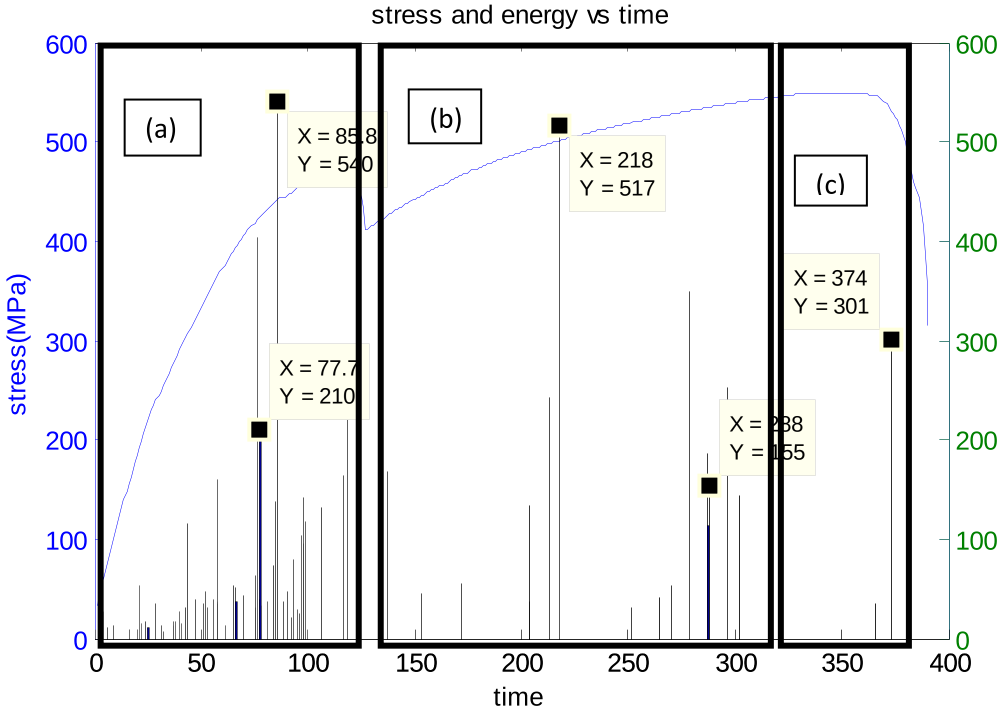


Figure 4.10: stress and energy versus time for welded specimen 1

The results recorded shows the stress-strain profile is not uniform, hence can be classified into 3 regimes, that is : (a) before tensile strength, (b) during plastic deformation which is between tensile strength and Ultimate tensile strength, (c) Instantaneous before and during final fracture or broken. The cracks are acting like a notch that will affect the stress contribution along the specimens by becoming un-uniform stress.

Localised deformation is identified as the main sources of AE because of the notch. During tensile test, the stress distribution will have more to the cracks hence the cracks having plastic deformation at the notch tip. It will emit frequent and higher AE signals compared to the base metal. The observation of increased in acoustic emission with increased notch length is parallel to the observation by Ishikawa and Kim, (1974). The strain-induced martensitic deformation cannot be taken as main sources of AE because of the no uniform stress contribution and uncertain amount of strain field associate with the localised deformation at the notch tip (Mukhopadhay et al. 2000).

In the regimes of before tensile strength or elastic region, the AE for welded specimens is higher than base metal. In base metal the sources of AE is by strain-induced martensitic deformation that emit lower AE because of lower stress or energy release. In welded specimens, non-uniform stress because of the cracks generated AE in continuous fashion. As the AE decreased by increasing the nominal strain at the second regimes is because of the blunting phenomenon, which is the notch tip is spread in huge volume (Mukhopadhay et al. 2000).

In third regimes, the base metal is fracture by gradual necking and the AE is not intense as the welded specimens. For welded specimens, there is tearing at the cracks hence the cracks is generating higher AE and the fracture is like a brittle material.

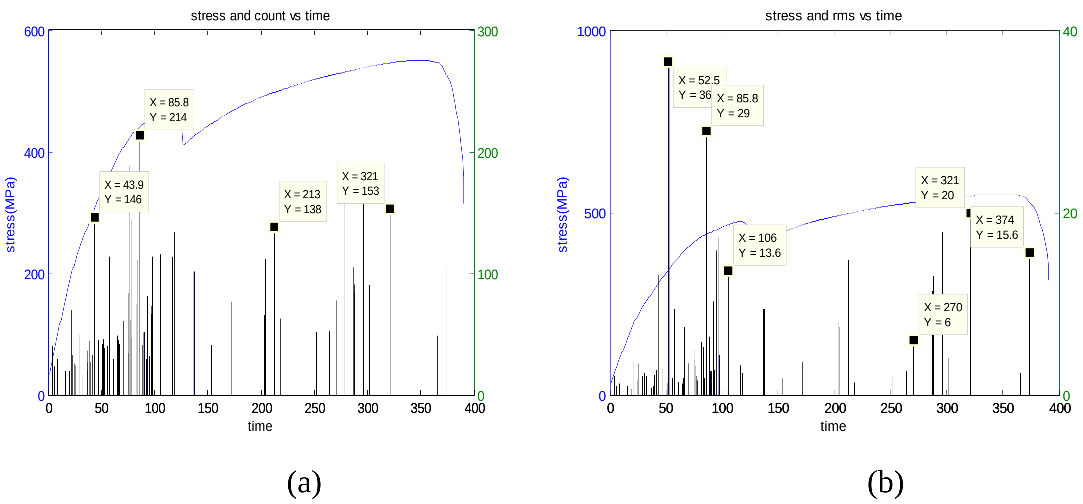


Figure 4.11: (a) Stress and count versus time graph, (b) stress and RMS versus time graph for welded specimen 1

Welded specimens have different characteristics compare to the base metal because they had undergoes high heating conditions and solidification that effects the grain structure. So the strength or tensile strength is different compared to the base metal. A weldment consists of weld metal, fusion zone, and heat affected zone (welding handbook, 2010). The highest residual stress acting on the weldment zone is in HAZ (Bang et al. 2011). Base metals that is adjacent to the HAZ having compressive stress that is changes from longitudinal residual stress at HAZ because of self-equilibrium (Ueda et al. 1988).

As stated before, the sources of AE for nuclear grade stainless steel is the dislocation activity and strain-induced martenstitic deformation. The welded specimens in this project were having defects called incomplete fusion and cracks. These cracks give huge impact to the fracture behaviour of the specimens because cracks are the worst defects of welding.

Figure 4.12 shows the energy distribution with respected to the time taken to complete the tensile test. Less of AE signals emitted compared to the welded specimen 1 and highest value is 540 at 74.2 second. Energy is elastic and plastic region is about to same with higher intensity of distribution at elastic region. Figure 4.13 (a) shows that the count distribution with respected to the time. Highest count is recorded on 74.2 second that is 276 during plastic deformation near the broken phase. The value of count seems not too much different between elastic and plastic region. Figure 4.13 (b) shows the RMS distribution and stress with respected to the time. The highest value of RMS is captured during 18.2 second with the value of 53.8 mV. It is stated on elastic region. The value of RMS in elastic region is quiet low compared to in plastic region shows the waveforms in elastic region is smaller than in plastic region.

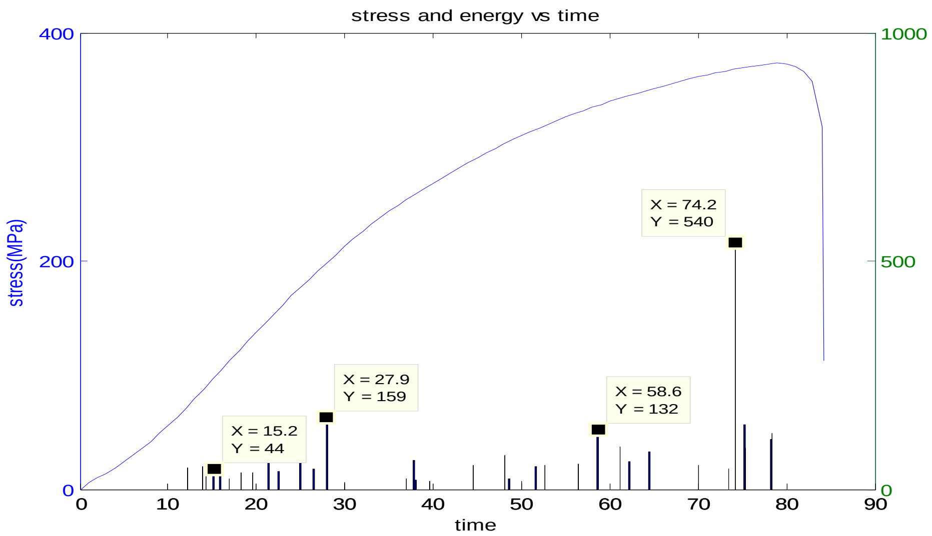
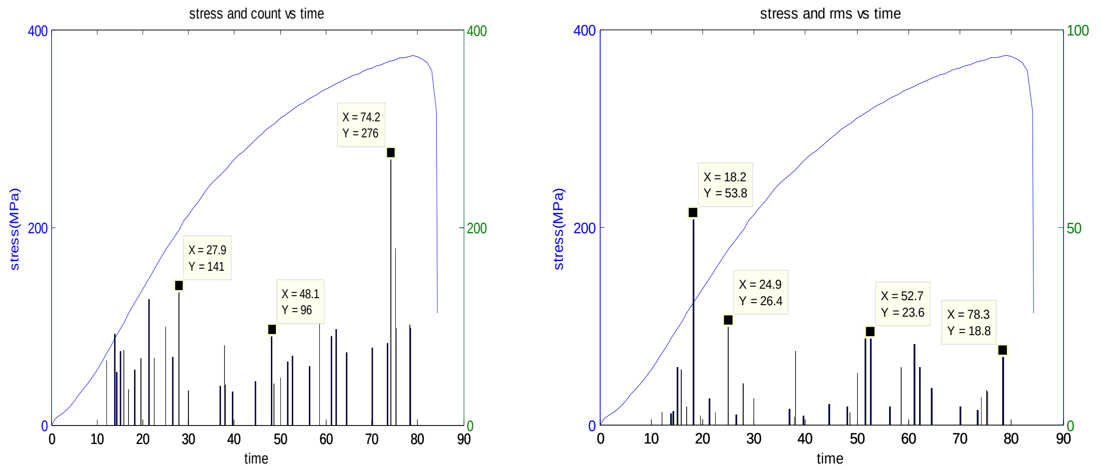


Figure 4.12: Stress and energy versus time for welded specimen 2



(a) (b)

Figure 4.13: (a) Stress and count versus time for welded specimen 2, (b) Stress and RMS versus time for welded specimen 2

Figure 4.14 shows the energy distribution by respected to the time taken to complete the tensile test. Highest energy is recorded at 54 second with value of 479. It is located before the specimen yielding. The value of energy is elastic region is quiet lower compare to the plastic region but there is high intensity in elastic region.

Figure 4.15(a) shows the count distribution throughout the test. The highest value is recorded during time period of 54 second with value of 262. It is also shows that the elastic region have higher count compare to the plastic region. Figure 4.15(b) shows the RMS distribution for the data chosen with respected to the time taken throughout the tensile test. The highest value of RMS is recorded during 59.4 second with value of 11.4 mV. The highest hit in energy and count at a time of 54 second just having RMS value of 1.8 mV. The frequent RMS appeared is about 1.6 mV to 4.2 mV.

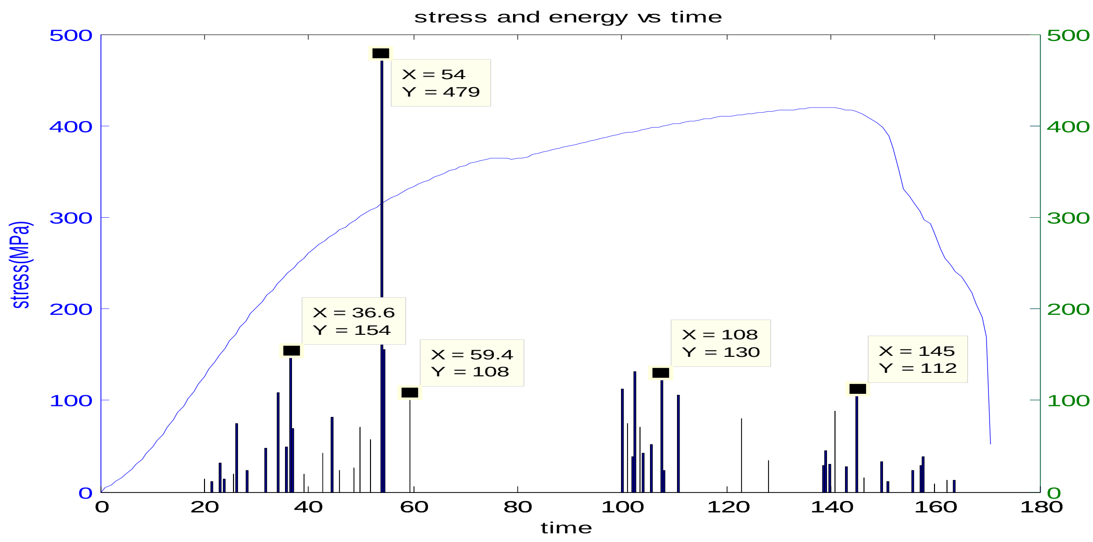
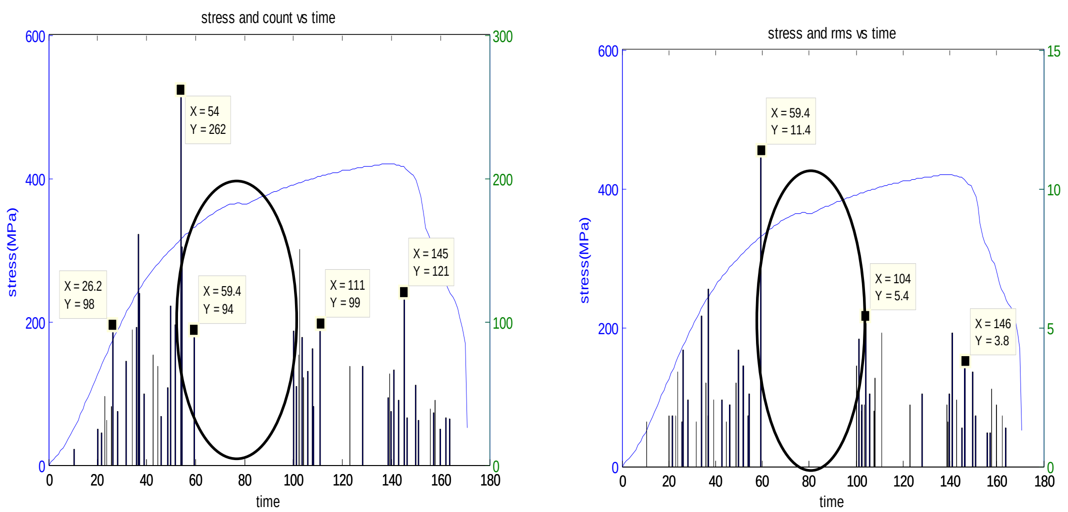


Figure 4.14: Stress and energy versus time for welded specimen 3



(a) (b)

Figure 4.15: (a) Stress and count versus time for welded specimen 3, (b) Stress and RMS versus time for welded specimen 3

The area in circle in Figure 4.15 is indicated that there is a phenomenon that is popular in acoustic emission, Kaiser Effect. This phenomenon happened when the applied load is removed, the AE signal will not emitted unless the load applied is more than previous load that is has been removed (AE sources, 2012). As the load were decreased with respect to the time due to change of phase from elastic to plastic, there were dropped in tensile load value. Many of dislocation and slips occur, hence the structure is not in elastic shape anymore. Then, the load was increased again until it fractured.

4.5 SUMMARY

As the summary, the welded specimens gives more AE signals compared to the base metal due to the local deformation and plastic dislocation at the cracks and tip of cracks. Major and bigger source of AE having in the welded specimen hence produce much more AE signals (Mukhopadhay et al. 2000). Kaizer Effect happened in base metal and welded specimen at the transition from elastic to plastic region. Higher value of AE properties such as energy, count and RMS also found in welded specimens. The tensile strength of welding specimens is lower than base metal because of the low quality of welding.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

As a conclusion, the AE properties are different due to the fracture behaviour of the material during tensile test. Less AE emitted for base metal because of the uniform stress contribution acting on the specimen. Higher AE emitted for welded specimens because of the non uniform stress contribution and there is huge dislocation activity during the tensile test because of the defects on the specimens. The defects are different for each of specimen. Specimen one is having width of cracks about 0.639 mm, specimen two is 1.425 mm and specimen three is 1.223 mm and 0.726 mm. Higher intensity or many AE emitted during elastic deformation, but reduced as the nominal strain increased throughout the plastic region. The AE signals become higher at the end or at instantaneous of final fracture. The tensile stress is higher for base metal with 632 MPa compared to welded specimens which are 410 MPa for welded specimen 1, 279 MPa for welded specimen 2 and 300 MPa for welded specimen 3. Hence all the hyphothesis and objectives had been achieved. Acoustic emission technique which is the real time monitoring is widely used in industry to as a condition monitoring technique to monitor the equipments such as pipes and pressure vessels condition. It is also used in monitoring the cracks of structure for buildings and to know the integrity and lifetime of the structure.

5.2 RECOMMENDATIONS

There is some recommendations can be made to enhance the result observed from this project

a). Make a 100 percent welded specimen which is do not have any defects as references or benchmark and to compare the AE signals that emitted from the defects welded specimen.

b). Do the NDT such as Ultrasonic testing or radiographic Inspection to know the quality of welding.

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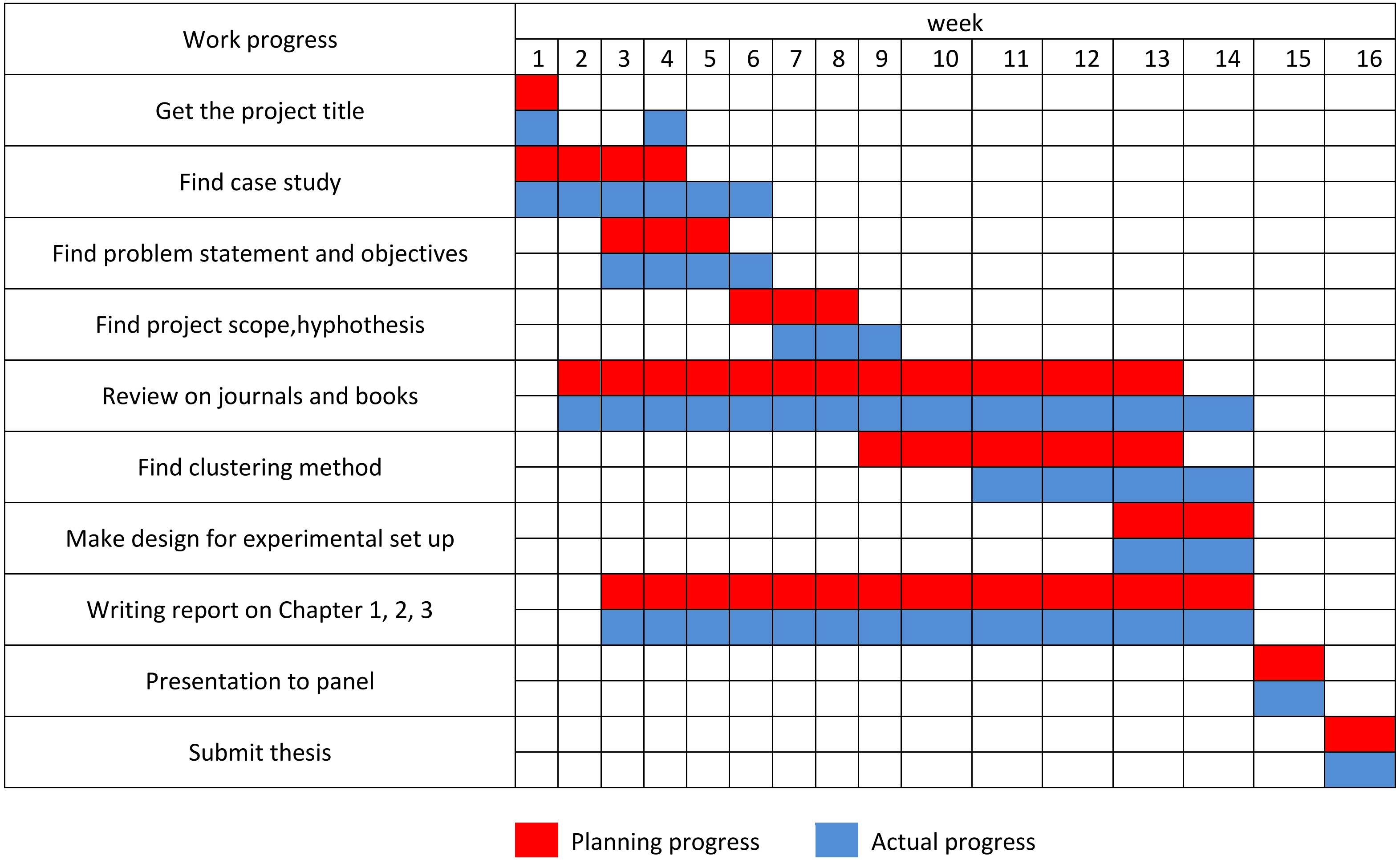
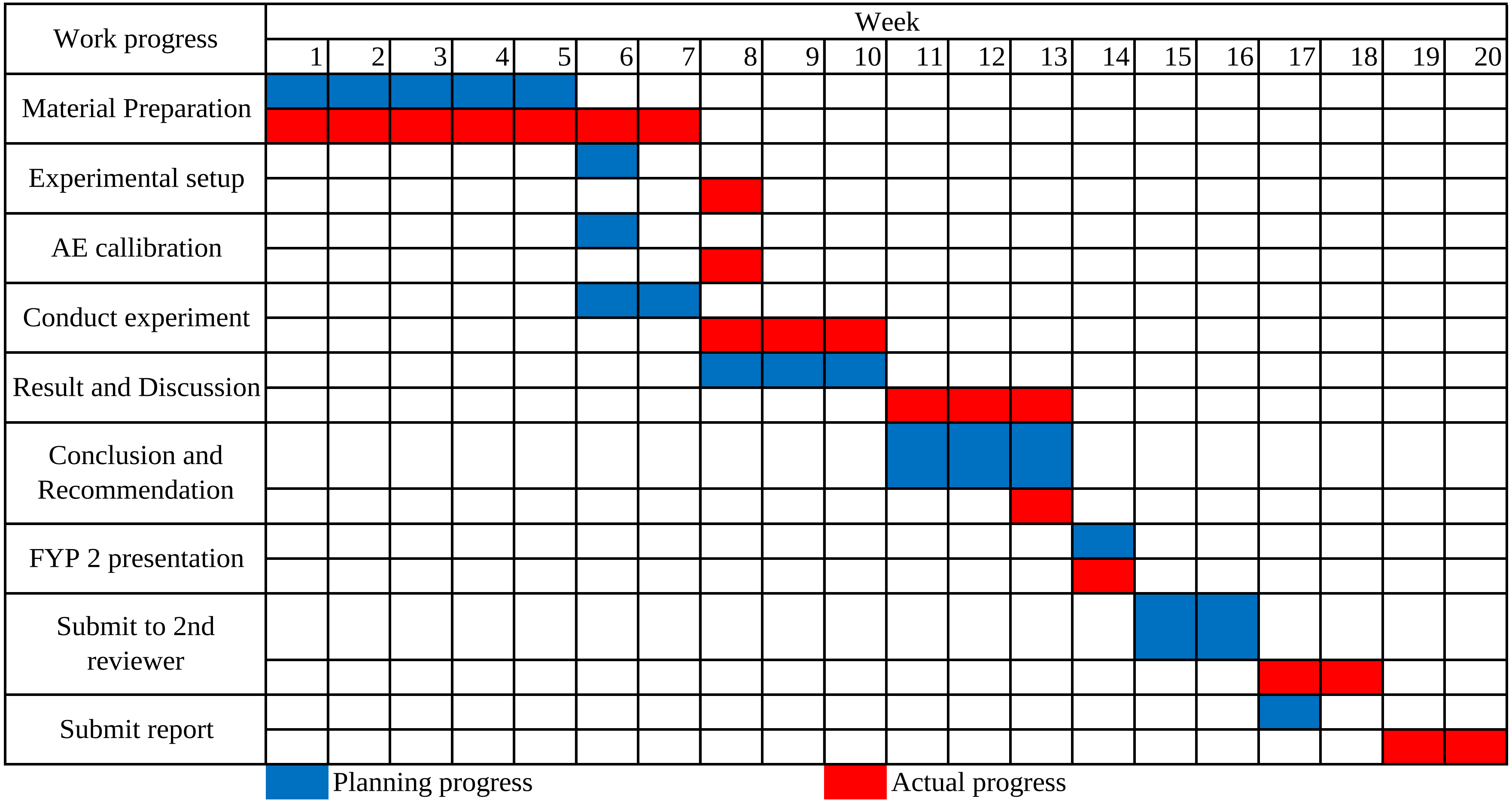
APPENDIX A1

GANTT CHART : FINAL YEAR PROJECT 1



APPENDIX A2

GANTT CHART : FINAL YEAR PROJECT 2



APPENDIX B1

DRAWING FOR TENSILE TEST SPECIMEN

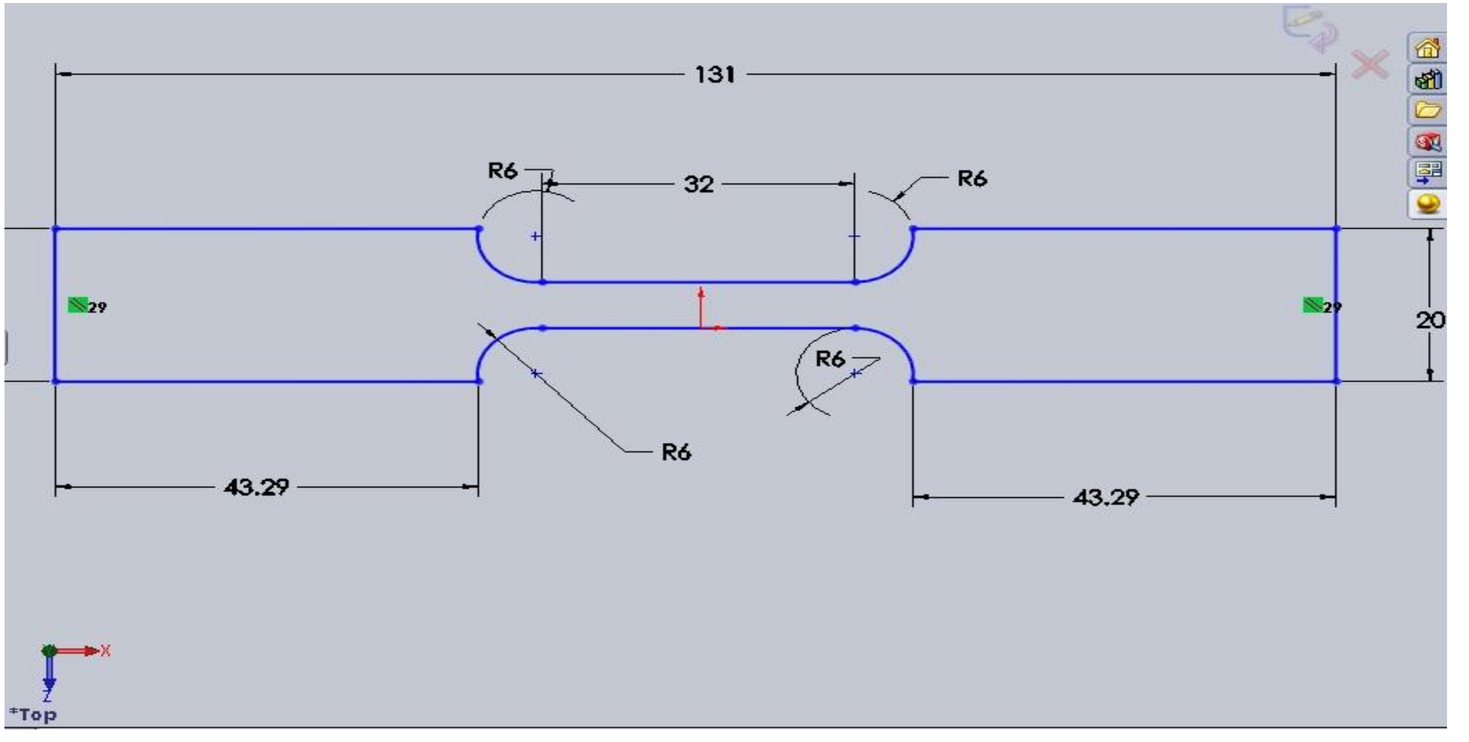


Figure : 2D drawing for tensile test specimen

APPENDIX B2

EDM WIRECUT PATH CUTTING

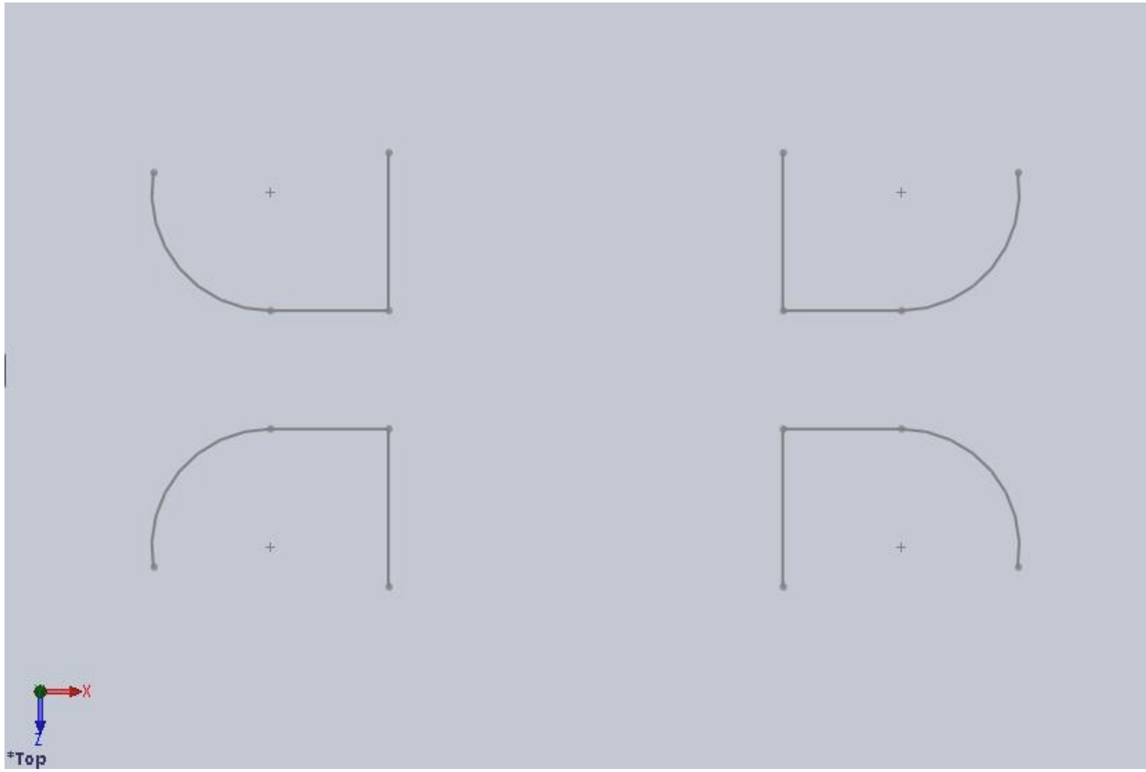
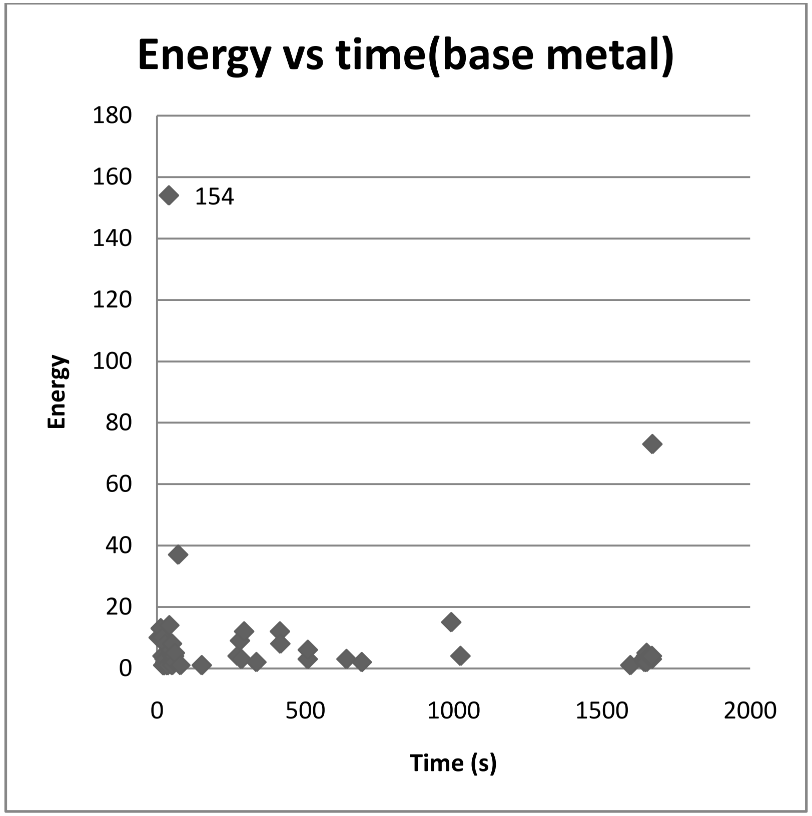
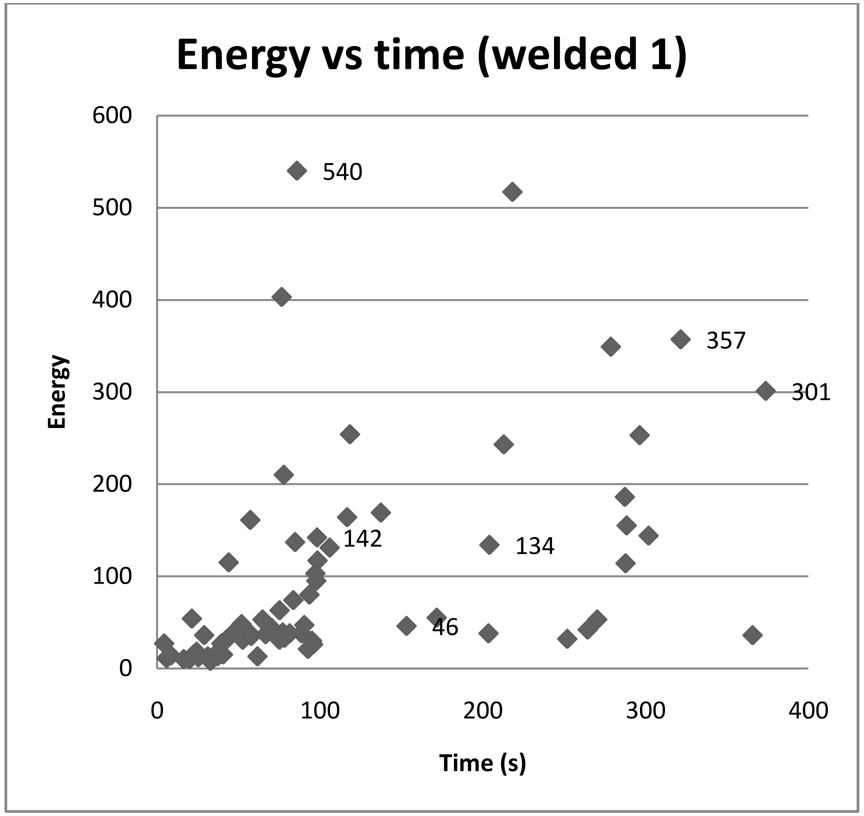


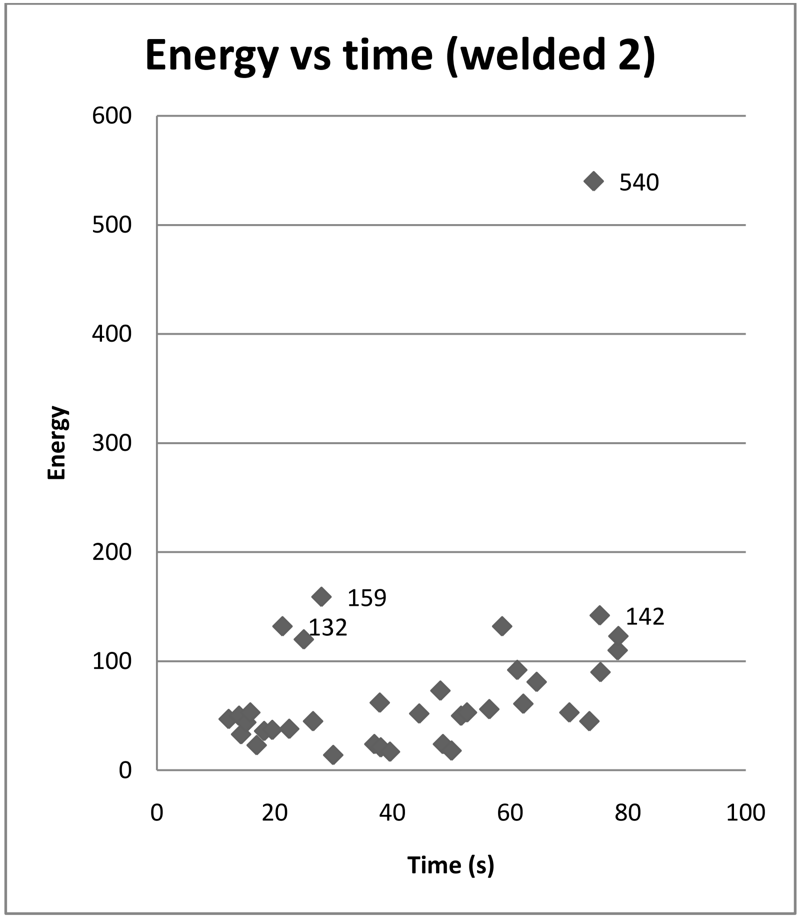
Figure : EDM wirecut path cutting for curving in tensile specimen

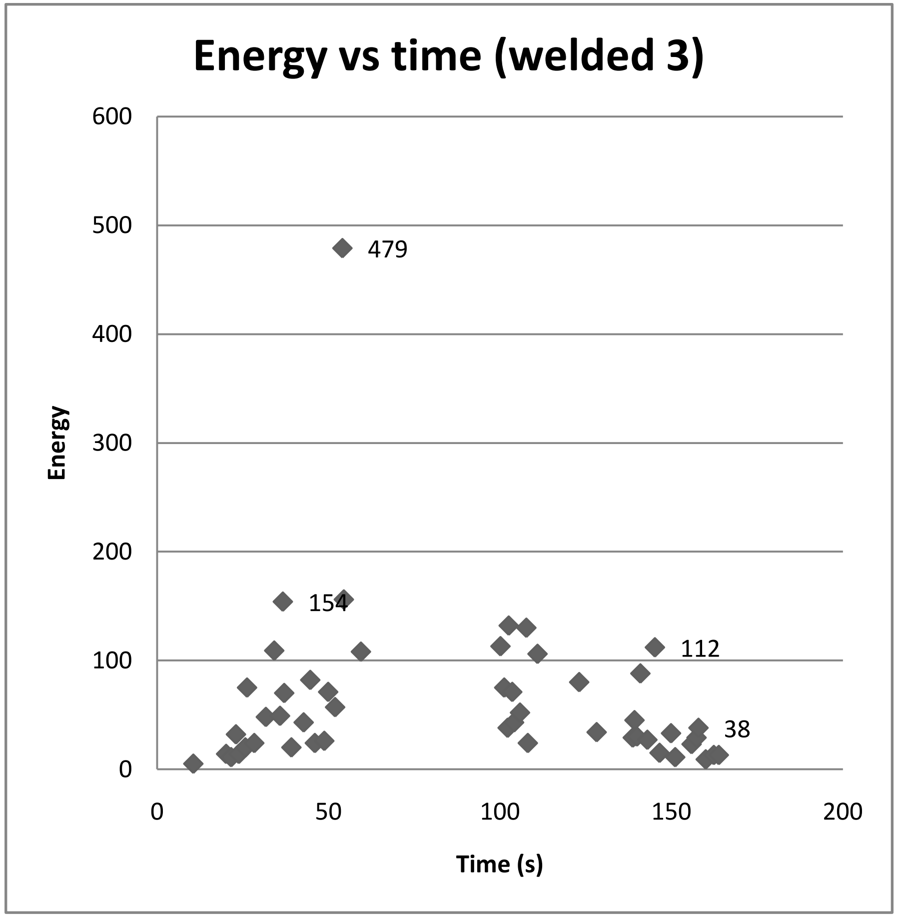
APPENDIX C

AE PROPERTIES WITH RESPECTED TO THE TIME

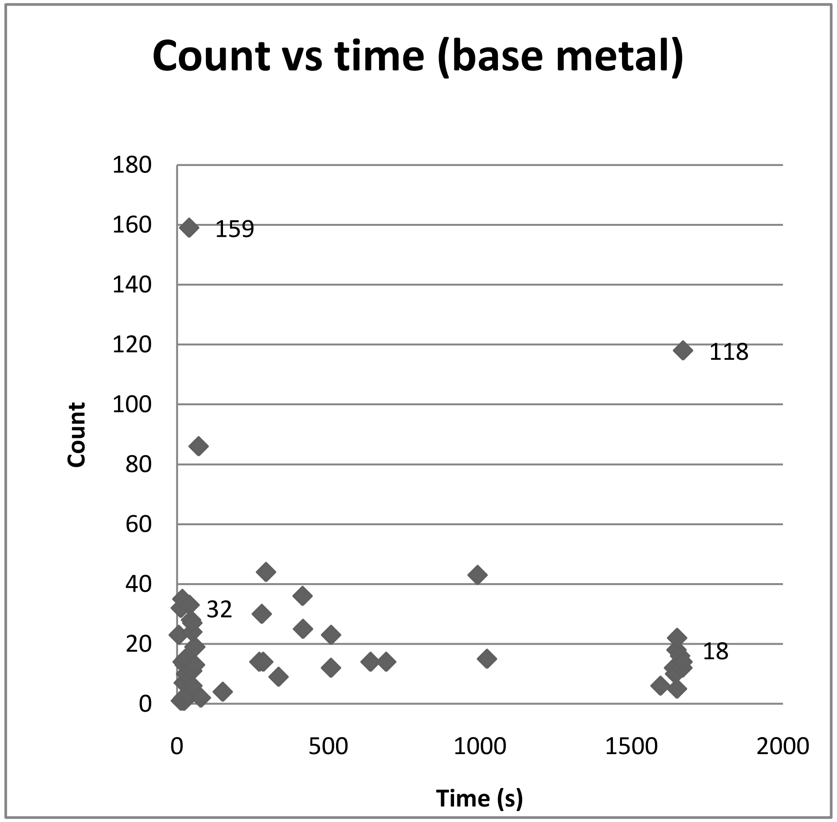


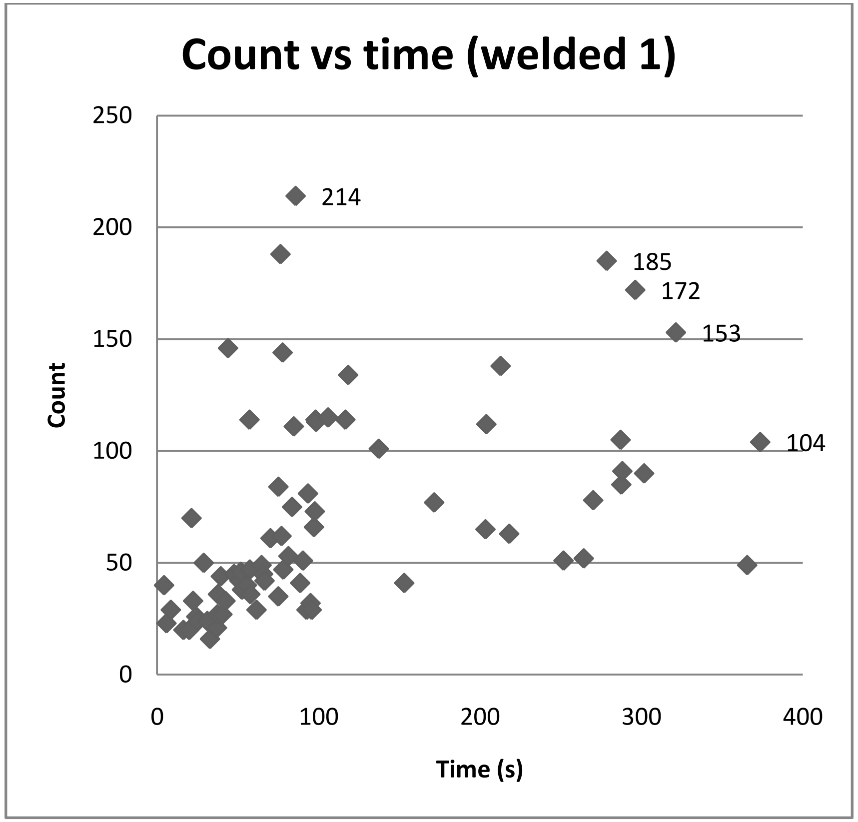



Energy vs time (welded 2)
Energy
Time (s)
600
500
400
300
200
100
0
0
20
40
60
80
100
540
159
132
142


Energy vs time (welded 3)
Energy
Time (s)
600
500
400
300
200
100
0
0
50
100
150
200
479
154
112
38

APPENDIX C (continued)





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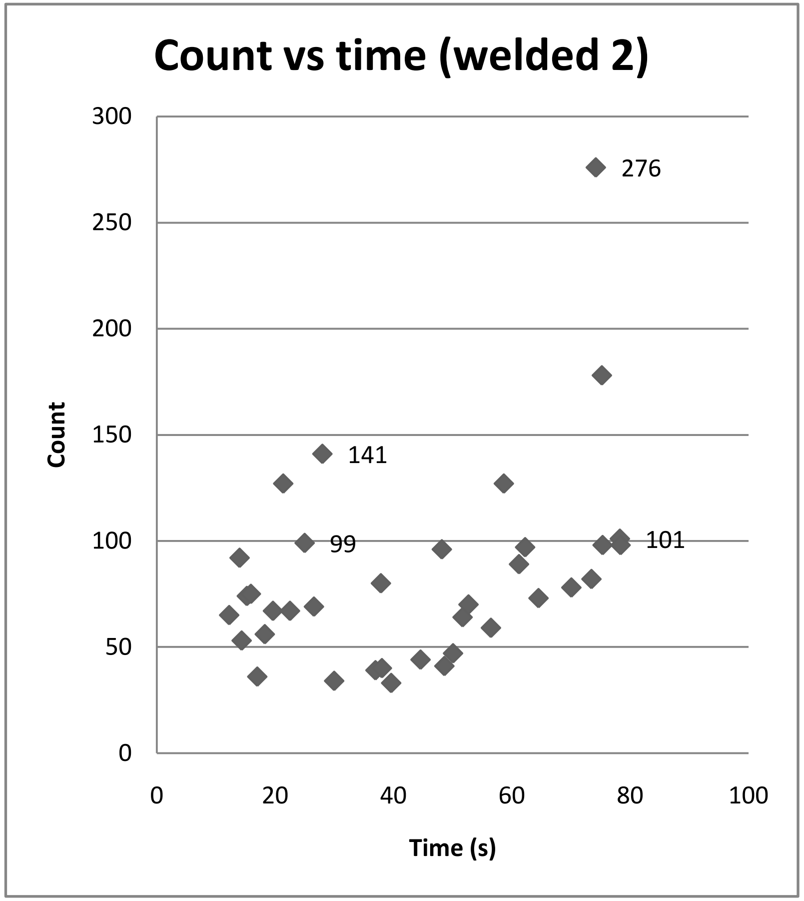

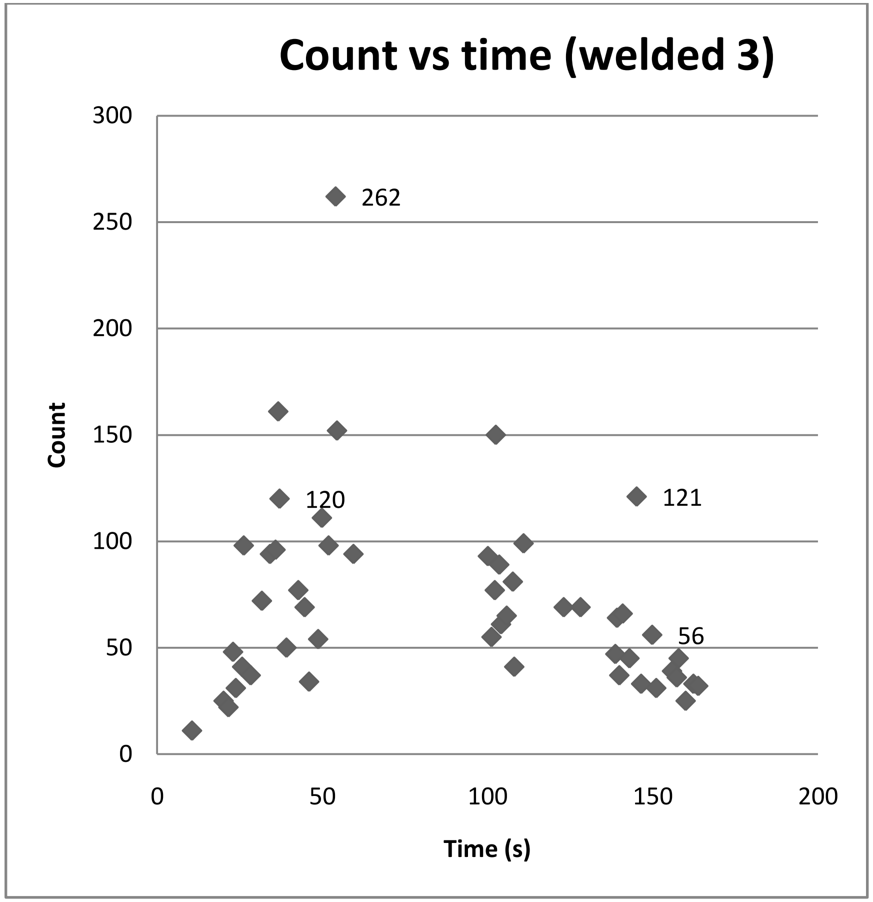

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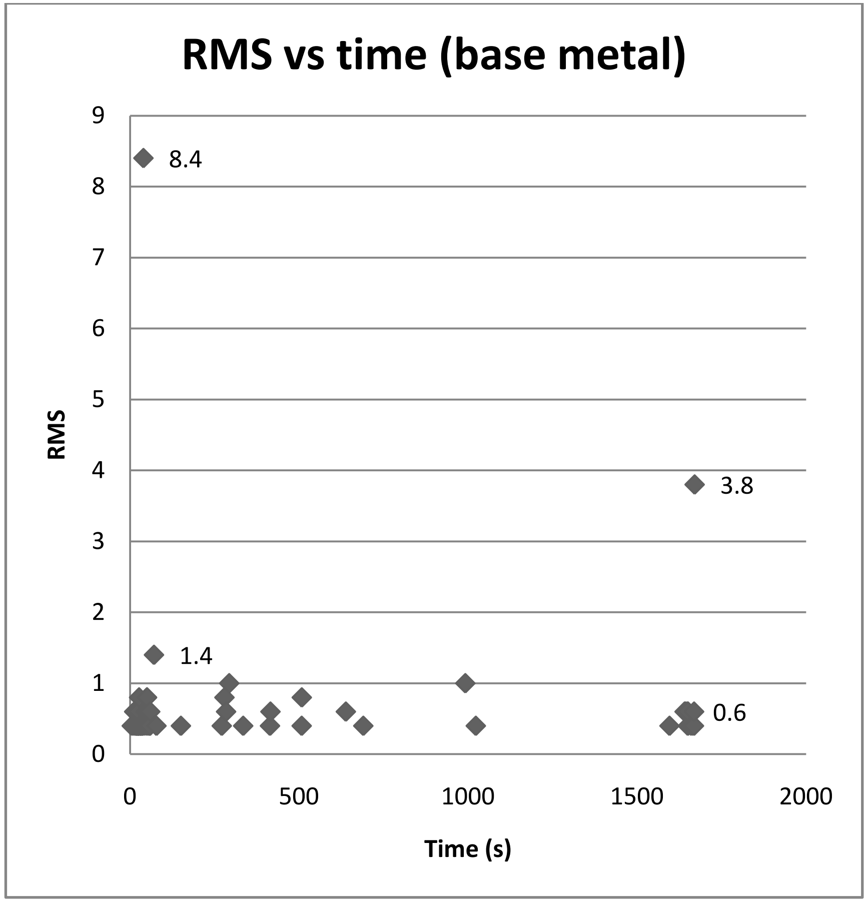

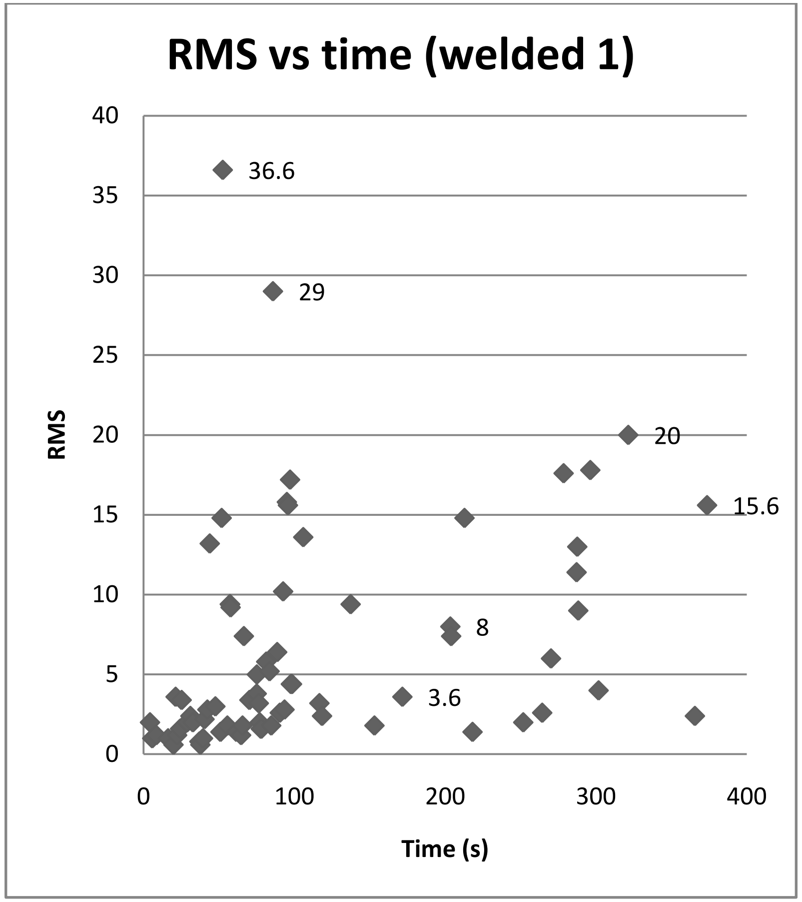

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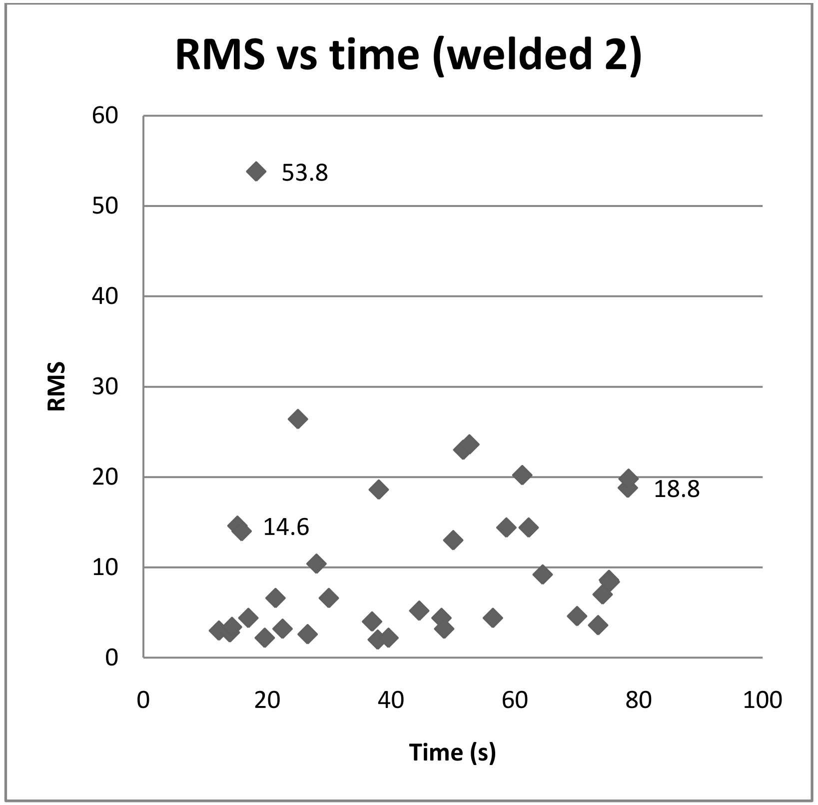
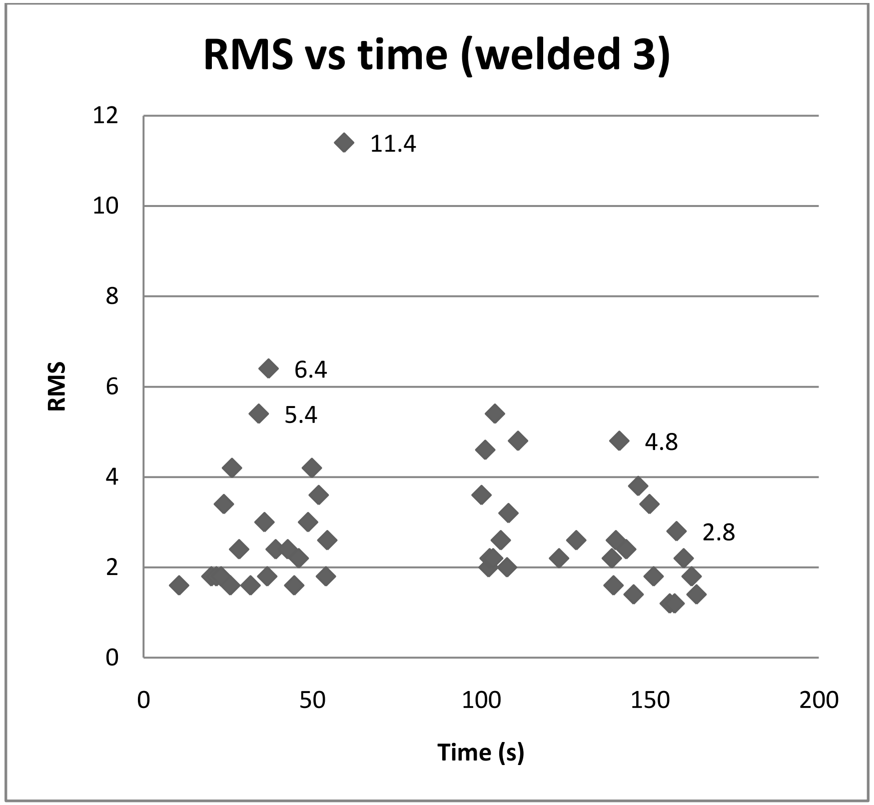




APPENDIX D

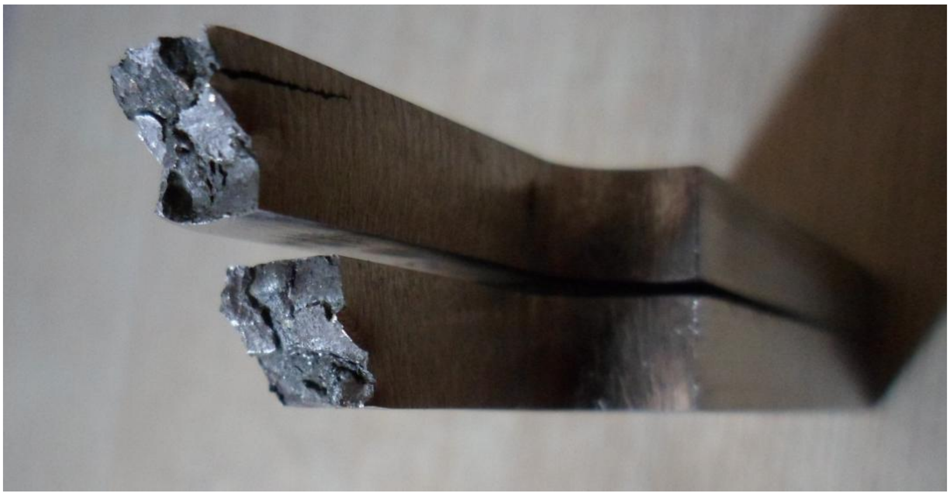
FRACTURE OF THE SPECIMENS (BASE METAL)

APPENDIX D (continued)

FRACTURE OF SPECIMEN (WELDED SPECIMEN 1)

APPENDIX D (continued)

FRACTURE OF SPECIMEN (WELDED SPECIMEN 2)



APPENDIX D (continued)

FRACTURE OF SPECIMEN (WELDED SPECIMEN 3)