A STUDY OF ACOUSTIC EMISSION TESTING ON MILD STEEL MIG WELDING

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Report submitted in partial fulfilment of the requirements
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JUDUL: A STUDY OF ACOUSTIC EMISSION TESTING ON MILD STEEL MIG WELDING

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SUPERVISOR'S DECLARATION

We hereby declare that we have checked this project report and in our opinion this project is satisfactory in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with "specialization".

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STUDENT'S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

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ABSTRACT

This project was carried out to study the availability of using Acoustic Emission (AE) technique on mild steel MIG welding. The objective of this research is to investigate the effect of welding joint between two types of mild steel and also to classify different type of signal characteristics occur on defected and non-defected welding joint. Test plans consist of two experiments. Experiment one was conducted to see the signal characters on defected welding joint meanwhile for experiment two for non-defected welding joint. The same procedures were applied for both experiments. MIG welding process was run to joint two plate of mild steel. The sensor then was located at five different positions for both defected and non-defected welding joint to capture the AE waves. The signals of AE were recorded using physical acoustic instrumentation. For all five positions on defected and non-defected welding joint, the value, of hits, counts, peak amplitude, RMS, and rise time were recorded and analysed were using Matlab. The result showed almost all parameters values for defected welding joint were higher compared to the non-defected welding joint. The results also show all parameters value highest at third position for both experiments due to weight of load. The conclusion has shown that the defected welding joint has produced higher number AE signal compared to the non-defected one due to error of stress location or cracks at welding joint.

ABSTRAK

Projek ini dijalankan untuk mengkaji kebolehan dan keupayaan menggunakan teknik Emisi Akustik dalam keluli lembut yang digabungkan menggunakan kimpalan MIG. Tujuan kajian ini dilakukan adalah untuk mengkaji kesan gabungan kimpalan antara dua plat keluli lembut dan juga untuk mengelaskan perbezaan jenis isyarat yang terhasil di atas kimpalan plat yang mengandungi kecacatan dan yang tidak mengandungi kecacatan. Pelan ujian terdiri daripada dua eksperimen. Eksperimen pertama dijalankan untuk melihat karaktor isyarat untuk gabungan kimpalan plate yangg sengaja dicacatkan manakala eksperimen kedua dijalankan untuk melihat karaktor isyarat untuk gabungan kimpalan plate yang tiada kecacatan. Teknik gabungan kimpalan MIG digunakan dalam kedua-dua eksperimen. Sensor ditempatkan di lima tempat yang berbeza untuk kedua-dua eksperimen. Isyarat Emisi Akustic direkodkan menggunakan alatan akustik fizikal. Untuk kesemua lima posisi yang telah ditandakan, nilai-nilai hits, jumlah dan RMS (rata-rata, minimum dan maksimum) direkodkan dan dianalisis menggunakan Matlab. Keputusan menunjukkan untuk setiap nilai parameter di atas gabungan kimpalan plate yang dicacatkan lebih tinggi berbanding dengan gabungan kimpalan plat yg tiada kecacatan. Keputusan juga menunjukkan semua nilai parameter tertinggi pada posisi ketiga disebabkan nilai pemberat. Kesimpulan menunjukkan gabungan kimpalan yang dicacatkan menghasilkan lebih banyak signal AE berbanding gabungan kimpalan yang tiada kecacatan disebabkan kesalahan lokasi tekanan atau keretakan pada gabungan kimpalan.

TABLE OF CONTNTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOL

$^{\circ}$	Degree
σ	True stress, local stress

SAMPLE OF LIST OF ABBREVIATIONS

AE	Acoustic Emission
MIG	Metal Inert Gas
NDT	Non-Destructive Test
ASTM	American Society for Testing and Materials
RMS	Root Mean Square
PZT	Piezoelectric
A/D	Analog to Digital

CHAPTER 1

INTRODUCTION

1.1 THE OBJECTIVE OF PROJECT

(i) To study the effect of welding joint between two types of mild steel
(ii) To study the effectiveness of acoustic emission testing on mild steel MIG welding.
(iii) To classify different type of signal characteristics on welding joint.

1.2 THE SCOPE OF PROJECT

This project focus on the following aspect

(i) Perform welding process of two different types of mild steel using Metal Inert Gas (MIG) welding.
(ii) Acquire acoustic emission signal near the welding joint using the acoustic emission acquisition system during welding.
(iii) Analyse the signal acquired using the acoustic emission acquisition system and Matlab.
(iv) Identify the different signal characteristic.
(v) Select the best type of mild steel to be welded.

1.3 PROBLEM STATEMENT

Two types of acoustic emission signal appeared during welding process known as useful and disturbances signal. The useful signal occurs because of essential changes in the melted region of the spot weld. Meanwhile, for the disturbances signal, it is because by the noises come from surrounding like noise in the electrical component, noise of cooling liquid and also noise from electrodes knocks. In order to specify the types of signal characteristic before and after welding process, the acoustic emission device was use with some analysis using Matlab software. The acoustic emission testing was carried out during welding process of two types of mild steel. The signal was captured by acoustic emission device and was interpreted to find the variable signal characteristics before and after the welding process take place.

1.4 PROJECT BACKGROUND

Acoustic emission analysis is one of the best and effective ways to monitor the welding process signal. Various types of signal characteristics will occur during welding process and to identify that kind of signal the acoustic emission device will be used in this project. Same like other materials and structures, welding process also involved in dynamic phenomena which has different characteristic sound sources. The main goal of analysing acoustic emission signal is to appropriate determination of acoustic emission. In this research, the different type of acoustic emission signal characteristic will record in other to classified either the signal is useful of just a disturbances signal. Before welding process, the best selection of material needs to be done. Different materials will produce different signals when the acoustic emission device attached to welding point. Mild steel is one type of material that was widely used in welding process. Metal Inert Gas (MIG) welding was effective welding type to use in joining the mild steel. MIG welding is an arc welding process that use as an electrode and as filler metal. In this welding type, the arc and weld pool occur will be protected by inert gas shield. MIG welding prefer some advantages that make it choose as a welding type. To make the welding process become fast, this MIG welding could be used because it provides high welding speed. Beside, this type of welding also provide very small heat affected zones that make easy to analysis the welding joint. Excellent oxide film removal during welding and an all-positional welding capability are two different thing that also become the reason why MIG welding is the most widely used to weld and joint two different type of mild steel.

CHAPTER 2

LITERATURE REVIEW

2.1 METAL INERT GAS (MIG) WELDING

This type of welding process was first used in the USA in 1940s in many applications like automotive manufacture and cross-country pipelines. It is an arc welding process that uses a continuously fed wire both as electrode and as filler metal. In addition, the arc and the weld pool being protected by an inert gas shield. MIG welding provide several advantages to their user. The example of MIG welding advantages are provide high welding speed, smaller heat affected zones than TIG welding, excellent oxide film removal during welding and an all-positional welding capability. Because of above advantages, the MIG welding is the most widely used in several applications especially in joining of mild steel.

Metal inert gas (MIG) welding is a process that melts and joint metals by heating employing an electric arc established between a continuous wire (electrode) and metals to be welded. Shielding protection of the arc and molten metal is carried out by means of a gas, which can be active or inert. In the case of aluminium alloys, nonferrous alloys and stainless steel Ar gas or mixtures of Ar and He are employed, whereas for steels the base of the shielding gases is CO_2. When using an inert gas, it is kwon as MIG process (Metal Inert Gas) and MAG when Metal Active Gas is used. MIG process is one of the most employed to weld mild steel.

There are three basics metal transfer in MIG process: globular transfer, spray transfer and short-circuiting transfer. In the globular transfer, metal drops are larger than the diameter of the electrode, they travel through the plasma gas and are highly influenced by the gravity force. One characteristic of the globular transfer is that this tends to present, spatter and an erratic arc. This type of metal transfer is present at low level currents, independently of the shielding gas. However, when using CO2 and He, globular transfer can be obtained at all current levels (Garcia, 2002).

On the other hand, spray transfer occurs at higher current levels, the metal droplets travel through the arc under the influence of an electromagnetic force at a higher frequency than in the globular transfer mode. In this transfer mode, the metal is fed in stable manner and the spatter tends to be eliminated. The critical current level depends on the material, the diameter of the electrode and the type of shielding gas.

In short-circuiting transfer, the molten metal at the electrode tip is transferred from the electrode to the weld pool when it touches the pool surface, that is, when short-circuiting occurs. The short-circuiting is associated with lower levels of current and small electrode diameters. This transfer mode produces a small and fast-freezing weld pool that is desirable for welding thin sections, out-of-position welding and bridging large root openings (Garcia, 2002).

The principal advantages of MIG welding are:

(i) Is possible to perform welds in all welding positions.
(ii) Rate deposition is roughly two times than SMAW.
(iii) Quality of the welds is very good.
(iv) Is possible to weld materials with a short-circuiting transfer mode, which tends to improve the reparation and maintenance operations.

2.1.1 Mig welding process

MIG welding process uses direct current with the electrode connected to the positive pole of the power source, DC positive or reverse polarity. Recent power source developments have been successful in enabling the MIG process to be also used with AC. Most of the heat developed in the arc is generated at the positive pole, in the case of MIG welding the electrode, resulting in high wire burn-off rates and an efficient transfer of this heat into the weld pool by means of the filler wire. When welding at low welding currents the tip of the continuously fed wire may not melt sufficiently fast to maintain the arc but may dip into the weld pool and short circuit. This short circuit causes the wire to melt somewhat like an electrical fuse and the molten metal is drawn into the weld pool by surface tension effects. The arc re-establishes itself and the cycle is repeated. This is known as the dip transfer mode of metal transfer. Excessive spatter will be produced if the welding parameters are not correctly adjusted and the low heat input may give rise to lack-of-fusion defects. At higher currents the filler metal is melted from the wire tip and transferred across the arc as a spray of molten droplets, spray transfer. This condition gives far lower spatter levels and deeper penetration into the parent metal than dip transfer. When welding aluminium the low melting point of the aluminium results in spray transfer down to relatively low welding currents, giving a spatter-free joint (Garcia, 2002).

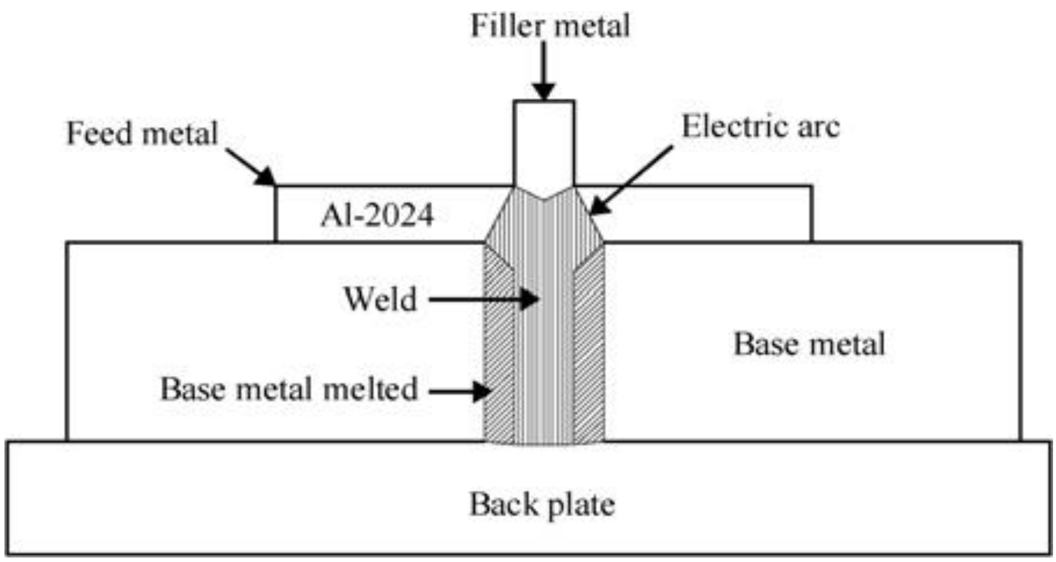

Figure 2.1: MIG welding process

2.1.2 Welding procedures and techniques

The MIG welding process takes several techniques to complete in very good condition. These techniques should be considered by MIG welding user to ensure the weld joint is in smooth and good condition. They are not to be regarded as hard and fast rules. But the parameters quoted form a starting point from which to develop a procedure especially designed for the applications. The rules and technique is clearly described below.

a) Arc Starting

Starting point of welding is an important consideration that should take note by the welder. This is because to avoid defects from occur, welder should strike the arc some 25mm ahead of the desired starts point and then move back to the weld start before beginning to weld forward at a normal speed. A welding process start when the wire begins to feed as soon as the trigger is operated and is short-circuited when it touches the work piece, establishing the arc. The current surge on short-circuiting may cause arcing within the contact tip and spatter to adhre to the shroud and contact tip. These can lead to wire feeding problems (Garcia, 2002).

b) Torch Positioning

Torch positioning is important in MIG welding to prevent damage to weld joint. The angle at which the torch is presented to the joint is important in that an incorrect angle can result in air entrainment in the shielding gas and will also affect the degree of penetration. Normally the torch should be normal to the surface and pointed forward towards the direction of travel at an angle of between 10° and 15° from the vertical. This type of angle also known as forehand angle. As this angle increase, penetration will decrease and the amount of air entrained in the shielding gas gradually increase. Arc length cannot be set by adjusting the voltage since this is a function of the resistance of the circuit as a whole. The arc length is set by the welder using both sight and sound, a correct arc length being characterised by a soft crackling sound similar to the sound of frying bacon. Too short an arc sounds harsh and gives excessive spatter while a long arc has a humming sound.

c) *Ending The Weld*

This part occurs when the weld is ended. At this time, the wire feed is abruptly stopped the weld pool will freeze and a shrinkage crater will form. If the weld pool is small this crater may be simply a shallow depression in the weld surface. To get very smooth weld joint, below method should be considered.

(i) The use of run-off tabs on which the weld can be terminated, the tab being subsequently removed.

(ii) Increasing the travel speed just before releasing the trigger. This causes the weld pool to tail out over a distance. It requires a high measure of skill on the part of the welder to produce acceptable results.

(iii) Making a small number of brief stops and starts into the crater as the weld cools. This adds filler metal to the crater.

(iv) As the trigger on the torch is released the wire feed speed and the welding currents are ramped down over a period of time. The crater is fed with progressively smaller amounts of molten filler metal as it forms, resulting in the filling and elimination of the crater. This crater filling facility is standard on modern equipment and is the preferred method for avoiding piping porosity and crater cracks.

2.2 OVERVIEW OF ACOUSTIC EMISSION (AE)

2.2.1 History of Acoustic Emission

Acoustic emission is an efficient technology to be use in an investigation about stress in materials. It is well known that every day we face with life phenomenon that relate with changing of stress in materials. The phenomenon like breaking glass, falling tree and cracking ice are some examples of fracture sound we may hear from different objects subjected to stress. In scientific, acoustic emission define as a phenomenon of sound and ultrasound wave generation by materials that undergo deformation and fracture process. Properties and environment factors are two different things that affected the characteristics of acoustic emission waves.

The history of acoustic emission starts in 8th century when the AE undergo two different eras which is pre-technological and technological. When pre-technological era people were observing acoustic emission signal without use any instruments. They just use their part of bodies to define what type of acoustic emission are occurs. The heard of cracking stones, fracturing of bones and cracking of wood in the fire are example how people in pre-technological era observe the acoustic emission signal.

Figure 2.2: A pre-technological man observes the wood condition either it is safe to pass over or not.

In 20th century the technological era has started to replace the pre-technological era. A few developments have been seen in this era. The researches started to mention about audible sound in their material deformation investigation. Reseacher like J. Czochralski noted the term of “tin cry” that show the audible emissions produced by mechanical twinning of pure tin during plastic deformation. Seven years later, A. Portevin and F. Le Chatelier come out with new investigation about different frequency of audible sounds that could be heard during plastic deformation of an Al alloys, manganase and copper. Then in 1924, P. Ehrenfest and A. Yoffe prove that the process of shear deformation of salt and zink is cause by clicking sound. After a decade, researches started to use an instrument in their acoustic emission signal investigation (Muravin, 2009).

Experimentation continued throughout 1950 when J.Kaiser wrote about effect of the absence of acoustic emission in materials under tensile stress. Beside, J.Kaiser also comes out with an investigation entitled “Result and Conclusions from Measurement of Sound in Metallic Materials under Tensile Stress. After a decade, J.Kaiser comes out with few of thesis and now his research accepted as a modern acoustic emission testing. After several years, researches from all over the world have been decided to create working group because they can see the development of acoustic emission technology quick running. Today, acoustic emission testing uses in industries all over the world and in many research centres worldwide.

2.2.2 Introduction of Acoustic Emission

Acoustic emission technology has been applied in lots of field like in education, medical, engineering and also as a research background. The development of acoustic emission is running very fast. Nowadays, acoustic emission becomes a non-destructive test (NDT) to detect some errors of stress location in mechanical loaded structure. Acoustic emission can provide information about discontinuity that occurs in mechanical loaded structure. Potters is an example of material that discontinuity occur in it stress location. Potters observed the sound emitting from the pots when deformations occur. This phenomenon actually becomes the first acoustic emission technique heard from metal.

Figure 2.3: Potters

The producing of acoustic emission signal is unique. It begins when some forces acting of mechanical loaded structure. Then because of that force the deformation take place and at once breakdown the structure of material at specific places. When this material breakdown, it produce some wave that move from wave source and travel through the body until it give signal to the remote sensor. This is what we called as an acoustic emission signal. The signal produce then will going to analysis part to assure it suitable to use the signal for further processing (Muravin, 2009)

There are several advantages and limitations that should be considered by researches to use this acoustic emission technique compare to others technique.

Advantages

(i) Can be used in many applications like monitoring, characterization, proving, detection and also relocation.
(ii) Easy to handle because it is a global monitoring.
(iii) Compactness and small weight of instrumentation.
(iv) Save energy and power when handle acoustic emission test.
(v) Material anisotropy is good
(vi) Reliability and convenience in usage.
(vii) Less failure occurs during test.

Limitations

(i) Repeatability will occur because acoustic emission is stress unique and each loading is different.
(ii) Attenuation that will disturb stress wave.
(iii)Can be subjected to extraneous noise.

The physical nature of acoustic emission in different materials is an important thing to understand to ensure the development of the acoustic emission technology become reality. The characteristics of acoustic emission and sources it generated are two different things that need to determine to ensure this acoustic emission technology is the best one to be used in engineering field. The functional properties of several materials are easy to change when those materials was tested by using acoustic emission technique. Because of this reason the non-destructive test (NDT) is introduced by researchers to avoid the changes of properties in test materials (Christian, 2008).

NDT actually is the technology of accessing the soundness and acceptability of a material, component or structure without change its functional properties. NDT method commonly used to detect and locate faults in mechanically loaded structure and component. The example of application that show NDT use to detect and locate faults is like detecting and locating in pressure vessels, damage assessment in fibre-reinforced polymer-matrix composites and monitoring welding applications and corrosion processes.

The NDT method is an original idea introduced by J.Kaiser in 1950s. At that time the phenomenon of sound emitted during crack growth became an issue that need to be investigated. The fast development in engineering technology just makes the AE testing become more complicated. Separating the useful information from the background noise was the challenge to the instrument developers.

The acoustic emission process takes several processes to complete. It starts with some forces acting on test materials body. The forces then will make some energy appears and will affected the stress structure of test materials. The stress occurs in materials structure also known as stimulus. The stimulus will make deformation take place and although will give damage to the material at specific places. This material breakdown produces an acoustic emission signal that will sense by using sensor. In response, the sensor produces an electrical signal, which is passed to electrical equipment for further processing (Christian, 2008).

2.2.3 Principle of AE Testing and AE Phenomenon

The generation of AE is a mechanical phenomenon, and can originate from a number of different mechanisms. Mechanical deformation and fracture are the primary source of AE, but phase transformation, corrosion, friction, and magnetic processes among others also give rise to AE. The energy thus released travels as a spherical wave front and can be picked up from the surface of a material using highly sensitive transducers, usually piezo electric type placed on the surface of the component.

Sensors are coupled to the structure by means of a fluid couplant and are secured with tape, adhesive bonds or magnetic hold-downs. The output of each piezoelectric sensor (during structure loading) is amplified through a low-noise preamplifier, filtered to remove any extraneous noise and further processed by suitable electronic equipment and analyzed to reveal valuable information about the source causing the energy release. Various types of other sensors are stain gages, accelerometers, electromagnetic acoustic transducers and optic of fiber-optic interferometers.

The frequency range of acoustic emission phenomenon extends from the infrasonic (<16Hz) into ultrasonic range. The largest and therefore the longest events such as earthquake are found at the lowest end of the scale while frequencies in the audible range occur predominantly in micro seismology i.e. during fracture phenomenon in rocks.

Acoustic emission in the proper sense covers the audible frequencies and the ultrasonic range. At higher frequencies, the acoustic emission is not intense enough in most cases and the material also absorbs large parts of the signal. The lower frequency limit is primarily set by the background noise.

2.2.4 AE Signal

The emissions from various sources outlined above are release as acoustic energy impulse. The energy thus released travels thought the structure as a spherical elastic wave to a detector, normally a piezo electric transducer which converts this acoustic impulse into electric signals. This electrical signal is then suitable processed and analyses to reveal information about the source causing the energy release. Two types of signals can be recognizing in general acoustic emission. There are:

a) Burst emission:

Burst emissions are discrete type of signals of very short duration (ranging from a few microsecond to a few millisecond) and hence of broad frequency domain spectrum. On the screen or monitor, they appear as individual signals or single needles well separated in time. Although these signals are rarely simple needle like, they usually rise rapidly to a maximum amplitude and decay in an exponential way to the level of background noise. Burst signal are characteristic of crack growth and propagation are also observed during twin formation as with the tin cry and micro-yielding.

b) Continuous emission:

If the acoustic impulses are emitted close to one another or if the burse very high then the signals occur very close and sometimes even overlap. In such case, the emissions are termed as continuous. In these types of emission, one cannot observe the individual signals separately.

2.2.5 Factor Affecting AE

Acoustic emission is the elastic energy that spontaneously released by materials undergoing deformation AE is thus a wave phenomenon and AE testing uses the attribute or characteristics of these waves to characterize the material/process.AE waveform is the convolution result of three effects; generation at the source, propagation and measurement. Two of the most common waveform parameters are frequency and amplitude. As indicated earlier, AE is a wide band phenomenon and frequencies can range from audible range to about 50MHz .The observes frequency spectrum of the AE signals greatly depends on the geometry and acoustic properties of the specimen and characteristic of the sensor.

In general practical applications, the background noise governed by the lower frequency limit which is normally about 10kHz while the upper frequency limit is dictated by wave attenuation. Most of the practical applications of AE testing are carried out in the frequency range of about 100 kHz to 300 kHz.

The sensitivity of AE method is primarily governed by the background noise. For the AE signal to be discernible, its amplitude should be clearly above the noise level.AE from metal, wood, plastic and other source can generate signal ranging from fraction of micro-volts to more than hundred volts. The dynamic range of the signal amplitude from the test object may be 120dB (V).When the conditioning would be required to visualize and interpret the AE signal reliably. Apart from this, prior to any experimentation, the noise sources should be identified and then removed or inhibited or limited.

2.2.6 Acoustic emission sources

As mentioned before acoustic emission occurs when the deformation take place in material structures or bodies. Besides that, acoustic emission also cause by growth of cracks, slip and dislocation movement, twinning and also transformations in materials. Acoustic emission is related to stress in any case. Stress is very familiar to use in many mechanical engineering test. There are five terms that suitable to describe stress which is tensile, compressive, bending, shear, and torsion. All this parameters have their magnitude and directions in a structure. Because of stress, several materials can return to their original shape or be permanently changed in the relative positions of the atoms in the material structure. If the stress is high enough, it can make plastic deformation occur that can disturb the movement of atomic planes that cause dislocations take place. This phenomenon will generate signal that we called as acoustic emission signal.

However, cracks also cause acoustic emission. There are two sources that give cracks on materials structure. The first source is known as emissive particles that occur at the origin of the crack tip. This particle are less ductile compare to the surrounding material and because of this reason, they tend to break more easily when the metal is strained. Since the materials completely strained, it gives result of acoustic emission signal that will sense by using sensor equipment. When metal is cracked, there are different types of AE sources take place and this one is the important one in non-destructive testing. The detection of AE signal from growing cracks has been used in many engineering application since it provide very efficient result.

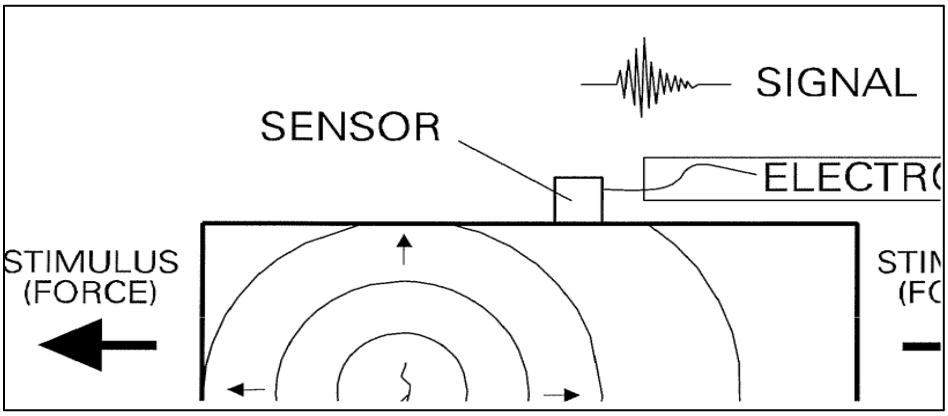

Figure 2.4: Acoustic emission process

2.2.7 Acoustic emission signal parameters

Acoustic emission parameters will appear when the AE test had been done. The example of parameters that usually occur when AE test run at several time are like peak amplitude, ring down count, rise time, event duration, AE count, AE energy, slope and etc. All those parameters are very useful to researchers to ensure their investigation complete successfully. The parameters above occurs when the transducer that received a signal that contains information on the rate of emission, frequencies of the emitted waves and amplitude.

a) Peak Amplitude

In acoustic emission testing, amplitude is refers to the largest voltage occur in the signal waveform. It can be measure when the amplitude is exceeding a predetermined threshold. These parameters usually measured in decibel (dB_{ae}) and the range is between 0 until 100 dB_{ae}. This amplitude can be related to the intensity of the source in the generally performance using a log amplitude to provide accurate measurement of both large and small signals (Christian, 2008).

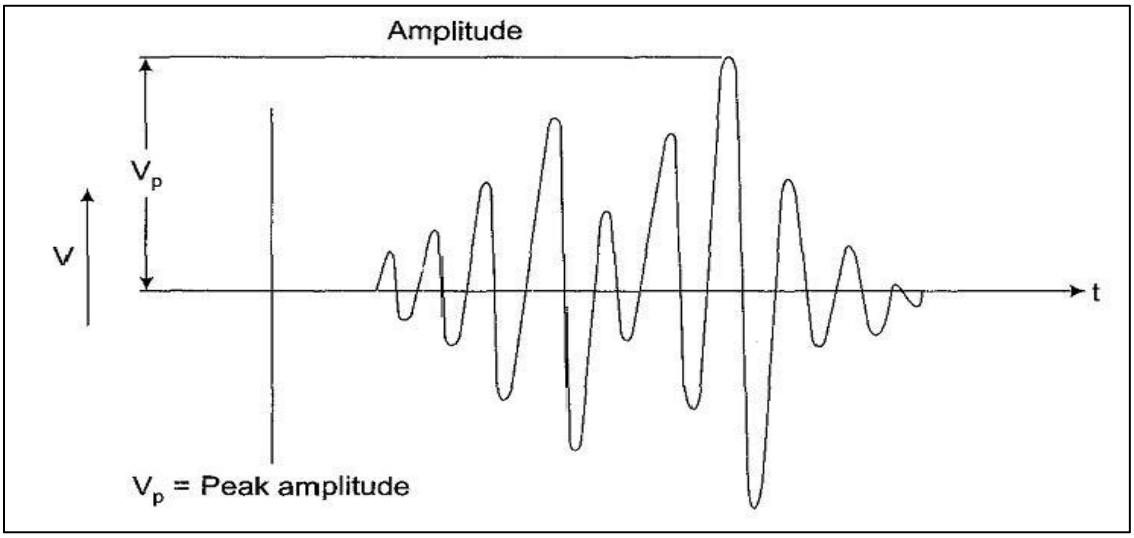

Figure 2.5: Peak amplitude wave

Source: Ndt Resource centre, 2001

b) Ring down Count

The ring down count is the comparator output pulse corresponding to the threshold crossings. In other word the ring down count also can be describe as the number of times acoustic emission exceeds a present threshold during any selected portion of a rest. The number of count is depending on the size and shape of the signal. The big signal size gives the higher number of counts. This parameter is very useful nowadays for data interpretation and also to can give information on signal shape (Christian, 2008).

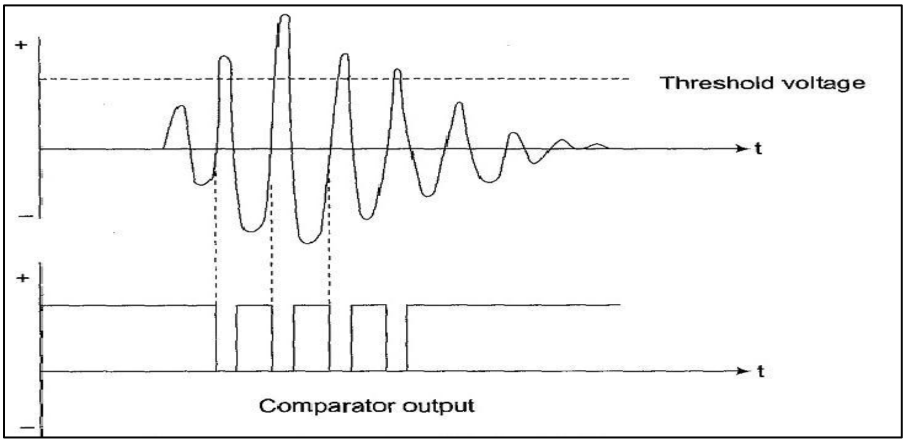

Figure 2.6: Ring down count wave

Source: Ndt Resource centre, 2001

c) Rise Time

Rise time can be known as the time required for the signal to reach its peak amplitude and normally counted from the time between first threshold crossing and the peak amplitude while decay time refers to the time taken by the signal to decay from its peak value to just above threshold level (Christian, 2008).

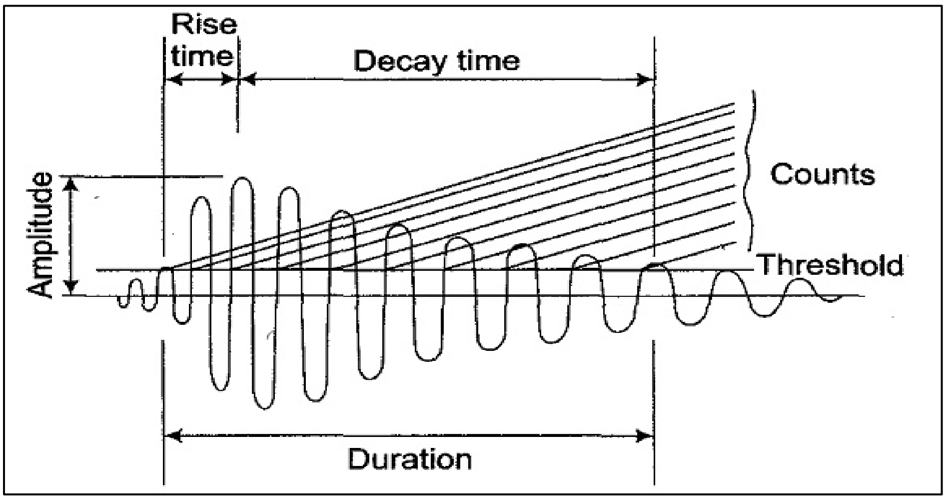

Figure 2.7: Rise time wave

d) Event Duration

Event duration in acoustic emission testing is known as the length of time between the first threshold and the last one. Materials that produce event duration parameters actually cause by microstructure displacement that make elastic waves take place and hence disturb load or stress in materials structure. Event duration commonly measured in microsecond. The relationship between event duration and amplitude affect signal shape in material either it is a short sharp click or a long drawn-out scrape (Christian, 2008).

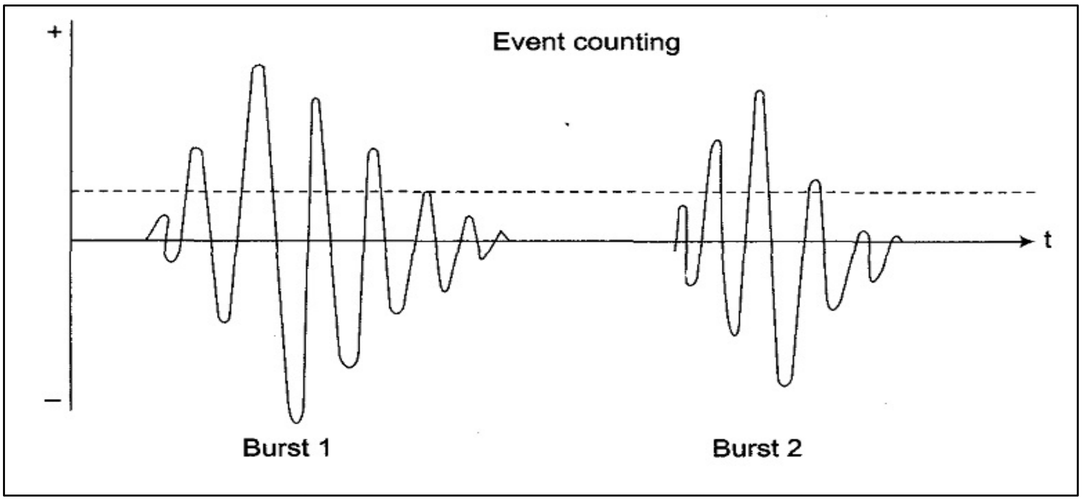

Figure 2.8: Event duration wave

e) Signal Energy or AE Energy

Other important parameters that need to be considered in acoustic emission testing is signal energy or also can be known as AE signal. This parameter occurs under the voltage-time graph and represent by dotted line as showed in the graph below. Signal energy is very important parameters and widely used in many engineering applications nowadays. When a structure produces many emissions in response to loading, the energies of the individuals signal can be added to produce total amplitude. Of all the techniques that have been used to describe emission quantity in a single number, this has been the most successful (Christian, 2008).

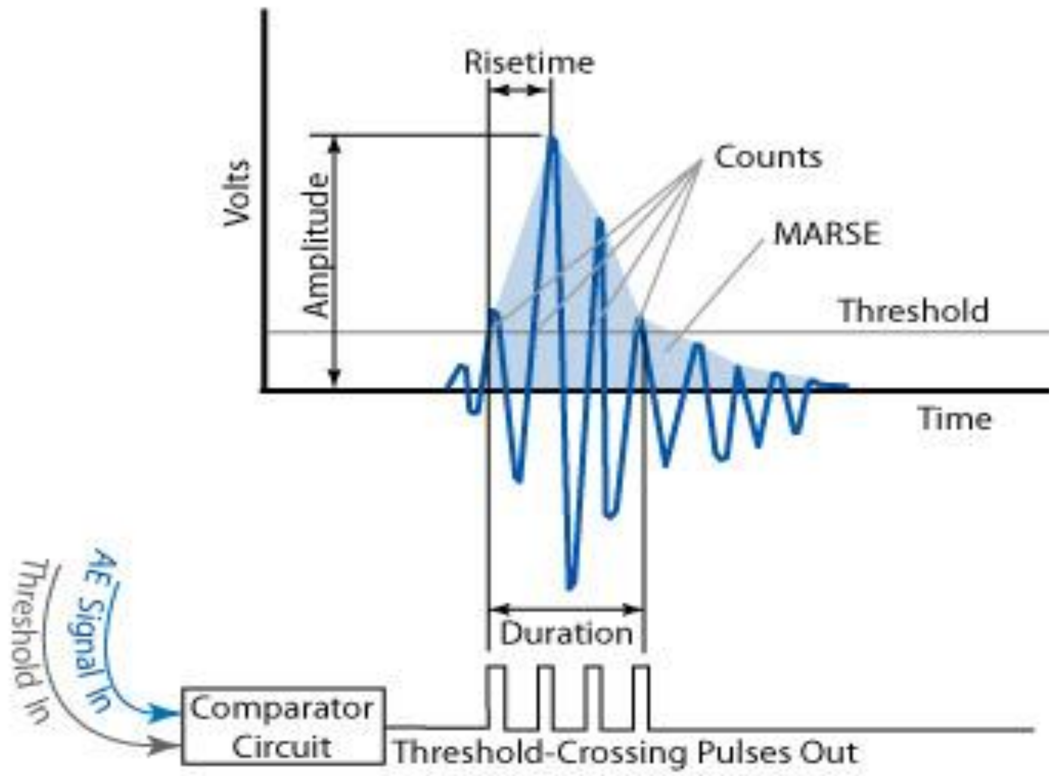

Figure 2.9: Parameters location of AE test

2.3 ACOUSTIC EMISSION SIGNAL AND INSTRUMENTATION

As mentioned before, acoustic emission was first use in analysis of seismology. At that time there is no sensor or instrument that was used by researches. But in early 1950s, Joseph Kaiser and his co-worker introduced the investigation of acoustic emission by using electronic instrumentation. After half decade, improvement of acoustic emission instrumentation was carried out by Schofield and Tatro. Different with Joseph Kaiser that tries to prove about irreversible activity, Schofield and Tatro bring new idea which called source characterization or dislocation. The improvement of acoustic emission was continued today where lots of new sensor and instrument was introduced by our researchers.

The instrument for processing acoustic emission signal was produce today in variety of form. The most important device in acoustic emission testing is sensors. Besides, other device like preamplifier, band pass, filter and circuit also important to assist in displaying the signal, analysing and recording depend on the application setting.

2.4 ACOUSTIC EMISSION APPLICATION

Acoustic emission is widely used in variety of structure and infrastructures in the field of mechanical and civil engineering. AE can be used as a monitoring and triggering device to several applications like concrete, wood, rock, superstructure of buildings and also to sub-structures including railway structures . Below are several applications that used AE as monitoring devices.

2.4.1 Concrete

Acoustic emission testing has been used in concrete engineering for approximately five decades. The AE technique was applied to the concrete engineering because the increase number of building damage that cause by earthquake urgently demand for maintenance and thus retrofit of reinforced concrete structure in services. The phenomenon that mention before results in the need for the development of advanced and effective inspection technique. Thus, acoustic emission gives a great attention to diagnosis applications in concrete. Below are several investigations that perform by researchers to repair concrete structure

a) Under Mixing – to control the consistency of fresh concrete.
b) Dynamic Compaction – to simply estimate the degree of compaction.
c) Drying Shrinkage – to study about micro cracking that cause by drying shrinkage.

2.4.2 Weld monitoring

The welding process will produce very high temperature that can change materials structure. During welding process take place, temperature changes induce stresses between the weld joint and the base metal. These stresses then are often relieved by heat treating the weld. Some cases, the weld is not possible and minor cracking occurs. This cracking can continue for up to ten days after the weld has been completed. In weld monitoring, stainless steel normally used as materials accelerometers for detection purposes and background noise monitoring (Masayasu, 2008)

Figure 2.10: Weld Monitoring

2.4.3 Substructure

A part of infrastructure such as footing, pile and pier is called a substructure which mechanically supports structural members of the superstructures. When the investigation of damage is done, the superstructure is readily inspected because visual inspection is normally available. In contrast, the assessment of damages in the substructure is often not an easy task. For example, pile- foundations installed underground deeply into bearing strata cannot be inspected visually. In this aspect, acoustic emission measurement is expected to become powerful technique for damage evaluation of the substructure.

2.4.4 Bridges

Bridges contain many welds, joints and connections, and a combination of load and environmental factors heavily influence damage mechanisms such as fatigue cracking and metal thinning due to corrosion. Bridges receive a visual inspection about every two years and when damage is detected, the bridge is either shut down, its weight capacity is lowered, or it is singled out for more frequent monitoring. Acoustic Emission is increasingly being used for bridge monitoring applications because it can continuously gather data and detect changes that may be due to damage without requiring lane closures or bridge shutdown. In fact, traffic flow is commonly used to load or stress the bridge for the AE testing.

CHAPTER 3

METHODOLOGY

3.1 METHODOLOGY DESCRIPTION

Methodology is one of the important parts that need to be completed by researchers to ensure the thesis or investigation follow the schedule. This chapter will clearly describe about the project procedure that plan to be run by researchers. By doing this chapter, it will ensure that the project or research is following the objective that have been stated earlier in chapter one. The most important parts that need to state in methodology are the step or design of experiment of the project. The researchers should know what parameters and materials actually relate to their project and that entire thing should be state in this methodology chapter. By using the objectives and scopes as the guideline, methodology can be described as the root of the research. Besides, methodology also can be described about anything or everything that can be encapsulated for a series of process, activities and tasks. All things that have been state before should come out with five term which is who, what, where, when and also why. For example when take some data; we should know what is actually used of the data we collect. Also where is the best location to place the sensor to get the best data. With this methodology, it is easier to indicate the problem in our research because it has step by procedure. The research will become easy to run if all things follow this methodology chapter.

The final year project is started with selection project titles by students. All students need to choose eight best titles that they think suitable and only one title have been given. At the first week of semester, some briefing and introduction about the project title has given by supervisor. The discussion about the objective and scope of experiment has been discussed in this first meeting. For several first weeks, some journal and articles that related to the thesis was found by student as preparation to writing introduction and literature review. Besides journal and articles, students also start to find books as their references.

After some information was found in article, the project was continuing with literature review chapter. In this chapter, it is about to find or gather all the information that related to this project. The overview about acoustic emission testing is an example of information that need to state in literature review. Besides, the theory, signal, parameters and instrumentation of the acoustic emission also need to discuss in literature review. All the information gathers from internet, journal, reference book and related person. After complete the literature chapter, the project continued by do some planning on how to run the acoustic emission testing on al Alloys that completely weld with MIG type of welding. The discussion about design of experiment should be done with supervisor. At this stage, some information like material structure, cost to assemble the materials and the size materials used need to consider by students. Then, student also should know about the principle and used of the acoustic emission instrumentation.

All the things that has mention before is very important to complete this project. To handle acoustic emission instrumentation is difficult because this device is very sensitive with noise. So then, the noise should be eliminating from project location. Before do the acoustic emission testing, the two types of mild steel need to weld first. Metal Inert Gas (MIG) welding is choose as welding type because of several advantages like provide high welding speed, smaller heat affected zones than TIG welding, excellent oxide film removal during welding and an all-positional welding capability. All this advantages make the weld joint suitable to make the AE test. When the test is complete, the data was collect and ready to analyse by using Mat lab software. At this stage, the important parameters like peak amplitude, counts, frequency and energy was discussed to see any different at each point location. All this discussion will state in chapter 4 which is result and discussion.

The report writing is done after the entire thing that describe above is complete. This process will be predicted to be finished in one week to arrange and accomplish. A report should follow UMP thesis format and also guidance by final year project supervisor. A slide also should be finished several weeks before presentation to final year project panel. The final year project finished when presentation is done and student submitted their draft to supervisor.

3.2 FLOW CHART

Flow chart that constructed below is guidelines to complete this methodology chapter. All procedure and design and experiment are simply described by using this flow chart.

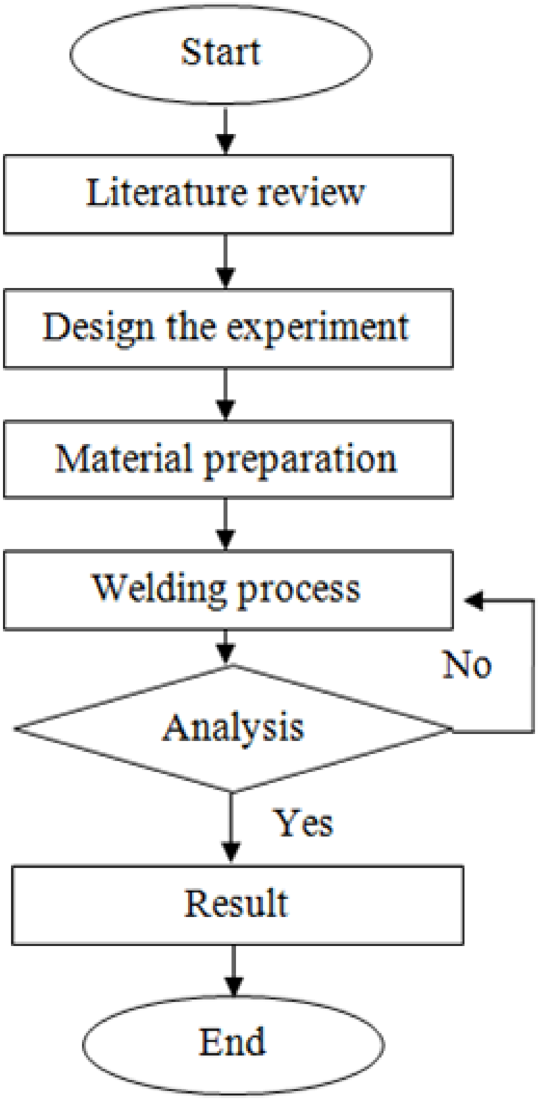

Figure 3.1: Project Flow Chart

3.3 COLLECTING INFORMATION

The most important information related to this project titles is about MIG welding, principle of acoustic emission and signal characteristic that produce by test materials. All these information was collected from several sources like internet, journal, articles, previous UMP thesis and also related person like supervisor and lab coordinator. For example the way to handle MIG welding is introduced by lab coordinator. There are lots of programs or seminar done by mechanical engineering faculty to help student learn how to use several machine without any fees. This is also one way how student get information to running their project.

3.3.1 Information from internet

The information from internet was most important to assure non-stop information about acoustic emission testing. Some graph, picture and articles that attached to report are from internet sources. Internet also used to gain information about acoustic emission and MIG welding.

3.3.2 Information from reference book

Most of information is from this source. Normally, reference book will clearly state about basic guideline about certain topic and it is very useful and suitable for student at this stage of degree. There are lots of book that related to acoustic emission testing but not all simply describe about basic guideline. After several inspections there are two books that useful as an information sources for this topic. That book was clearly stated below.

1) Christian U. Grosse, Masayasu Ohtsu. 2008. Acoustic Emission Testing-Basic for Research-Applications in Civil Engineering
2) Ferdinand P. Beer, E. Russell Johnston, Jr, John T. DeWolf, David F. Mazurek. 2009. Mechanics of Materials- Fifth Edition In SI Units.

3.3.3 Information from related person

The related person that was related to this project is the supervisor that guide on how to elaborate the concept of the acoustic emission and MIG welding. Supervisor also is the person that giving some advice and shoe the way how to write the proper report. Also related person was the student that doing project that was related to the acoustic emission although the major title is different. Those people give an advice and proper method to perform the experiment. Some discussion has been held to get a best solution of certain issues. Besides, the related person also the lab staff that always gives useful information about the software and instrumentation.

3.4 DESIGN OF EXPERIMENT

This chapter will clearly describe about the experiment setup in order to found out the different signal characteristics that cause by welding process between two type of mild steel. As mentioned in chapter 2, the acoustic emission signal occur when some wave move from wave source and travel through the body until it give signal to the remote sensor. This signal is an important to be analysed. The result will be in set of data and will analyse by using Mat lab software. The design of experiment is an important one to ensure a signal characteristic that occurs in unstable material condition is easy to be found.

In this experiment, two type of mild steel will be used as weld joint. Both of this al Alloys will measure with same size and length and will weld by using MIG welding type. When MIG welding take place, the acoustic emission instrument will attached to the welding joint. Sensor is one of the important devices in acoustic emission testing and will be placed on the mild steel surface. Between the sensor and mild steel will be couplant that is grease. The couplants used in acoustic emission testing to provide a good contact between the test object and the sensor. The smooth contact required when test take place to ensure the acoustic emission parameters will be carried out without any mistake occurs.

The welding process just run after two plate of mild steel was completely filing. After welding process done, the sensor will attached to the end of mild steel surfaces. That will be the first point for the acoustic emission devices. The next point will be located around 30 centimetres from the first point. The acoustic emission will be located about five point on the weld joint depend on how long the mild steel ready for the experiment. At each point the program will be running at least 60 second to get the signal. The signal produces then will analysed by using Mat lab software.

When analysing process take place, the acoustic emission signal need to be determined. As mentioned in Chapter 2, the signal like peak amplitude, frequency, ring down count, rise time, event duration, AE count, and AE energy are example of signal that will be occurred. All this signal parameters occurs when the transducer that received a signal that contains information on the rate of emission, frequencies of the emitted waves and amplitude.

3.5 SAMPLE PREPARATION

At this stage, the material was prepared with correct dimension and size. Four specimens from different type of mild steel was prepared with same length and thickness. The length of al Alloys was planned to cut with 180 centimetres in length and the thickness is around 2 centimetres. The thickness should be not lower than 2 centimetres to prevent any serious crack from occur. When welding process take place, a sensor will place at the top of weld joint between two types of mild steel. Other devices that also will use during the acoustic emission test perform are describes below:

3.5.1 Sensor

Sensor is an important device in acoustic emission testing. This device will attach at the top of surface to be tested. The function of this device is to convert signal detected which is dynamic motions at the surface of a material become electric signal. After the converting was complete, the electrical signals are amplified and filtered. Fracture in material takes place with the release of stored strain energy, which is consumed by nucleating new external surfaces or cracks and emitting elastic waves, which are defined as acoustic emission waves. The acoustic emission waves propagate inside a material and are detected by sensor. This is an example how the sensor can find the cracks occur in materials.

There are lots of sensor types that used by researchers in their acoustic emission investigation. Compared to other type of sensors, it is well known that the piezoelectric sensor is the best one. This type of sensor provides several advantages like can reduce testing cost, high sensitivity, easy to handle and the important one is selective frequency responses. In the case of piezoelectric (PZT) sensors, the sensors are usually operated in resonance. The signal produce are recorded in a small frequency range due to the frequency characteristics of the sensor to enhance the detection of AE signal. Very damped sensors are operated outside their resonance frequencies allowing a broadband detection, although they are usually less sensitive to wave motions.

Besides piezoelectric sensors, there are other sensors that have been used by researchers today. The laser system sensor was introduced for acoustic emission detection. This kind of sensor is contactless measurement and very sensitive compared to the piezoelectric sensor. The laser system is applied to acoustic emission measurement in ceramics under firing. This is because cracking under firing of structural ceramics causes a serious problem for fabrication. Cracks are generated in heating, sintering or cooling, so that acoustic emission monitoring was applied to optimize firing conditions.

Other type of sensor is an optical fibre sensor. This kind of sensor is a new development introduced by researchers that more attractive and alternative compared to the piezoelectric sensor. The advantages of this optical fibre sensor are long term monitoring, the condition free from electro-magnetic noise and the use of corrosive and elevated environments (Masayasu, 2008)

3.5.2 Preamplifier

The main purpose of preamplifier is to minimize the amount of electronic noise. This device commonly located near the sensor to ensure the sensor produces charge proportional to source intensity. Beside to minimize the amount of electronic noise, this device also used to amplify the small sensors signal so that they can be transmitted over long signal cables. Preamplifier also used to provide means of common mode rejection to reduce electrical pick-up from the sensor and sensor cable. Very good preamplifier should have several characteristics like low noise, low output impedance, moderate high gain, good dynamic range, high stability, good common mode rejection and input impedance matching to the sensor (Christian U. Grosse, 2008)

Figure 3.2: Preamplifier

Source: Ndt Resource centre, 2001

3.5.3 Filter

It is very difficult to differentiate the type of AE signal occurs in materials structure if the frequency is at higher state. So, then the filter is used to decrease the frequency to ensure signal characteristics will be classified. Filters are design for different bandwidth and can be plugged to preamplifier to meet the specific requirement. A filter of variables band-width between 1 kHz and 2 kHz is generally employed. The choice of the frequency range actually depends on noise level and attenuation property of several materials. An ideal filter allows the desired frequencies with unit gain and rejects any unwanted frequencies.

Figure 3.3: Filter

Source: Ndt Resource centre, 2001

3.5.4 Data acquisition converter

The main concern of this device is for converting and triggering. When handling this device, the fast analogue to digital (A/D) units need to be used to ensure a large number of events are recorded. Normally, the A/D converter is equipped for each channel of recording unit. Anti- aliasing filters are required so that the signals can be properly transformed to frequency domain.

Figure 3.4: Data acquisition converter

3.5.5 Couplants

The couplants used in acoustic emission testing to provide a good contact between the test object and the sensor. The smooth contact required when test take place to ensure the acoustic emission parameters will be carried out without any mistake occurs. The good couplants have several characteristics like higher corrosion resistance, sufficient viscosity, high wet ability and easy to remove. This device normally, made from natural wax, silicone grease and epoxy propylene.

3.5.6 Waveguide

Waveguide is a device used when the sensor failed to place directly on the surfaces of the component for acoustic emission monitoring especially when used in high temperature applications. The waveguide isolate acoustic emission sensor from bad environmental conditions of high temperature / nuclear radiations and make sure acoustic communication between the object under investigation and the sensor are maintain.

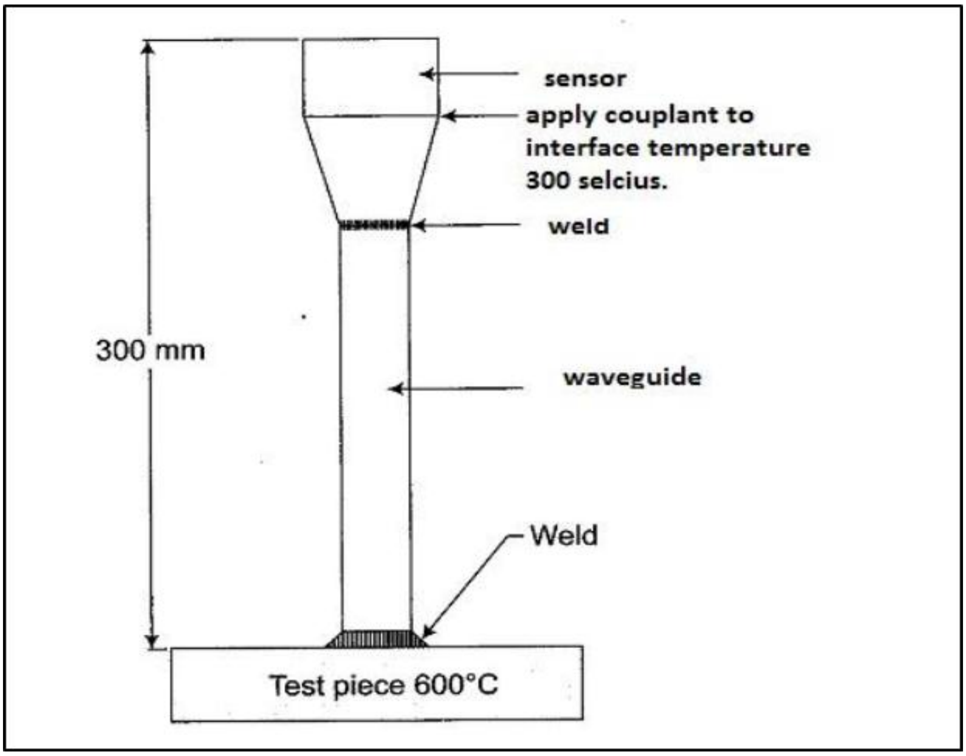

Figure 3.5: Waveguide

3.6 EXPERIMENTAL WORK

The acoustic emission testing start just after the design of experiment and acoustic emission instrument completely setup. The sensor that already attached to the weld joint can detect some unstable wave that produces the signal of acoustic emission. A signal triggering is conventionally made by setting threshold. In that case, only the signal that the amplitude exceeds the threshold levels is recognized as AE signal. Termination of the AE signal or the duration is determined as the period when the signal does not exceed the voltage threshold.

After sensor success to sensored the amplitude exceeds the threshold levels, all signal parameters and characters are determined. The peak amplitude is one of the important signals that need to determine. This signal refers to the largest voltage occur in the signal waveform. The next signal that needs to determine is ring down count. This signal can be describe as the number of times acoustic emission exceeds a present threshold during any selected portion of a rest. Other parameters or signals that also contribute in this experiment are rise time, event duration, and AE energy.

3.7 DATA COLLECTION

At this stage, the set of data like peak amplitude, rise time, counts and energy was collected to analyse. Ten points from different location will locate by sensor to get all signals that already mentioned. Below is example of experiment table that constructed.

POINT	PEAK AMPLITUDE		RING DOWN COUNT		RISE TIME	EVENT DURATION		ENERGY
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

Table 3.1: Signal parameters by point

3.8 AE ANALYSIS

The data that collected during acoustic emission will analyse by using Matlab software. The signal characteristic that occur during AE test will see at all five points but in different value. From the data also, we can know the acoustic emission testing is specified or not to use it in study of materials structure. The problem that involved in this testing is the noisy from surrounding. The noise from surrounding will disturb the effective of signal that produce so then also disturb it characteristics. The signal will first measured by using sensor. After sensor snap the signal, it will going to data acquisition converter to increase the signal size. The data acquisition converter also use to converting and triggering the signal to become simple one to analyse. A lots number of hits and counts will occur and all this parameters will analyze by using Matlab software.

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

For Final year project 2 the Mild Steel plate was welded by using MIG welding technique in order to create some signal characteristics that occur on welding joint. Those processes were conducted at welding and vibration laboratory. As mentioned in the previous chapter, there was two tests were conducted to achieve the objective of this project .Firstly, the experiment was conducted to test the acoustic emission device on the welding joint of mild steel before the joint was defected. It is same procedure for the second experiment, but the acoustic test was done after the joint of mild steel was defected. Note that, some of the result from this experiment shows the same pattern for each one of them. This was happening due of certain errors that occur during the experiment and the factor will be discussed in this chapter. In this chapter was show the result that get from both of the experiments that was conducted and will also discuss about the result and the error that occur during the experiment.

From previous chapter, the acoustic emission method is one of the NDT methods; where it can be done online, thus lower the cost of monitoring process. The advantages when using this technique is it can be used to only sense the specific defect by recognizing the pattern signal that appear. Another advantage is this method is noise tolerant, which mean, the data is free from unwanted signal. This has been proved by two simple tests where the sensor is placed to the welding joint before and after the joint is defected.

Common procedures that need to follow before the acoustic emission device can be use is to make sure the signal is in stable condition. The threshold value needs to be set in the software setting before recording can be done. The proper selection of the threshold is necessary to allow better form of signal can be shown. If the value is too high, no signals or hits maybe recorded. Meanwhile if the threshold value is too low, the signals may appear as continuous signal instead or burst signal. Note that, burst signal form is better in term of recognizing the pattern of AE signals.

4.2 DETERMINING LOCATION OF AE SOURCES

It is important to know the source of the AE signal before any test was conducted. The sensor must be placed in right location to get the best signal characteristics. The intensity of AE signal will decrease as the distance from any AE source increase. Noticed that, the signal characteristics like peak amplitude, ring down count, rise time, event duration and signal energy was recorded to see the differences between welding joint before and after the joint are defected.

As mentioned in chapter two, acoustic emission occurs when the deformation take place in material structures or bodies. In this experiment, two plate of mild steel was welded by using MIG technique. One joining was welded with smooth surface without any defect but another one joint was welded with lots of defect. To ensure the signal of acoustic emission can catch by sensor, some weight was hung at the end of welded joint between two plates.

4.3 ACOUSTIC EMISSION CLASSIFYING

The main objective of this study was to differentiate between acoustic emission signal characteristics like peak amplitude, counts, rise time, event duration and signal energy on two plate of welded joint in order to see the availability of acoustic technique to use in welding process.

From lots of data that measure from this experiment, only 9 or 10 signal was used. These data were taken in term of peak amplitude, counts, rise time, and event duration. The filtering of data was make to ensure that the data was relevant to taken as a final result and can be analyse.

Table 4.2 below show the welding parameters that had been use when welding process take place. It is very difficult to have welding joint without any defect because of the welding device not work in good condition. Because of welding machine is an old one, the welded process not run in efficient condition and it's become the main disturbed factor for this experiment.

Table 4.1: Welding parameters

Welding Condition	Current (amp)	Travel Speed (m/mm$^{2)}$	Travel Angle (°)	Result
Without Defect	50-100	320	10° and 15°	
With Defect	100- 140	450	30° until 45°	

In table 4.2 above are welding parameters that had been changed to ensure the welding results occur in two conditions which is defected and non-defected. To avoid defects from occur, welder should strike the arc some 25mm ahead of the desired starts point and then move back to the weld start before beginning to weld forward at a normal speed. The MIG welding process takes several techniques to complete in very good condition. These techniques should be considered by MIG welding user to ensure the weld joint is in smooth and good condition. They are not to be regarded as hard and fast rules. But the parameters quoted form a starting point from which to develop a procedure especially designed for the applications. Another step to ensure the weld quality is smooth is by increase the travel speed. As mentioned in table 4.2, the defect is occurring on welding joint when travel speed is decreased.

4.4 EXPERIMENT 1

Experiment 1 was conducted to capture the AE signal at defected position on welding joint. To ensure the defect occur on welding joint, some errors or mistakes intentionally run. Normally the torch should be normal to the surface and pointed forward towards the direction of travel at an angle of between 10° and 15° from the vertical.

In this experiment, the angle was added to the higher number between 30° until 45° to ensure defect occur. Beside, as mentioned before, the travel speed and current voltage also have a relation to defect the welding joint. By decrease the travel speed of wire feeder and current voltage, the defect will occur on welding joint.

When welding at low welding currents the tip of the continuously fed wire may not melt sufficiently fast to maintain the arc but may dip into the weld pool and short circuit. This short circuit causes the wire to melt somewhat like an electrical fuse and the molten metal is drawn into the weld pool by surface tension effects.

Figure 4.1: Defected welding joint

Figure 4.2: Experiment setup for defected welding joint

4.5 EXPERIMENT 2

All step and procedure for experiment 2 is almost the same with first experiment. Figure below show the result for first experiment. For experiment two, the sensor was located at the mild steel joint that had been welded without any defect.

For every single experiment, the sensor was located at five different locations. The timer started after a few second before the Physical Acoustic software collect the data. This gap of time was needed to ensure the acoustic emission device was in stable condition and to prevent the other unwanted signal be a disturbed factor in order to take an appropriate signal that was needed. The long period of this gap of time was better and can increase the percentage to get the right signal.

In this experiment, the data was collected at five different positions along welding joint. One side of the welding joint was clamp by using F clamp and the other side was hung with 40N weight. This weight was used in this experiment to generate stress that can response AE instrument to sense the AE waves. Sensor was located at point which is 10mm from right side of welding joint. After the AE instrument captured the data in txt format, AE sensor was located at another location that have 30 mm gap between each position.

Figure 4.3: AE data converter.

Figure 4.4: Sensor

4.6 SIGNAL PARAMETERS ANALYSIS

Table 4.2: Number of hits for defected and non-defected welding joint at all point

	Experiment 1	***Experiment 2***
Point	**Number of hits**	**Number of Hits**
1	82	11
2	83	4
3	113	25
4	75	13
5	51	17

Table 4.2 above show the number of hits for both defected and non-defected welding joint at all points. The comparison in term number of hits occurs when sensor was attached to the welding joint. As mentioned before, experiment one is refer to the defected welding joint meanwhile experiment two is refers to non-defected welding joint.

From the table above, the number of hits for defected welding joint was higher compared to the non-defected welding joint at all point. This condition shows that the source of the acoustic emission signals was from the defected welding joint. When welding joint was defected, local dynamic movements such as initiation and propagation of cracks, twinning, slip dislocation movements, phase transformation and fusion will disturb material composition and release the energy. The energy released travels as a spherical wave front and is converted as electrical signal by transducers placed on surface of the material and this signal called as AE signal.

The volume and characteristics of the AE generated dependent on the source characteristics, the principal characteristics of the source being its initial severity, current state, local metallurgical structure and current environment. This statement clearly shows that non-defected welding joint produced lower number of hits because local dynamic movement run smoothly in this non-defected joining. Figure 4.5 and figure 4.6 show trend of hits for both defected and non-defected welding joint.

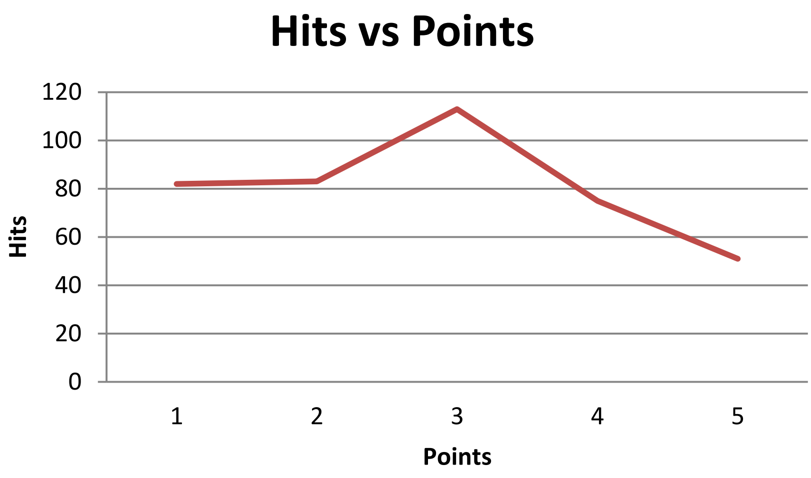

Figure 4.5: Graph hits versus point for defected welding

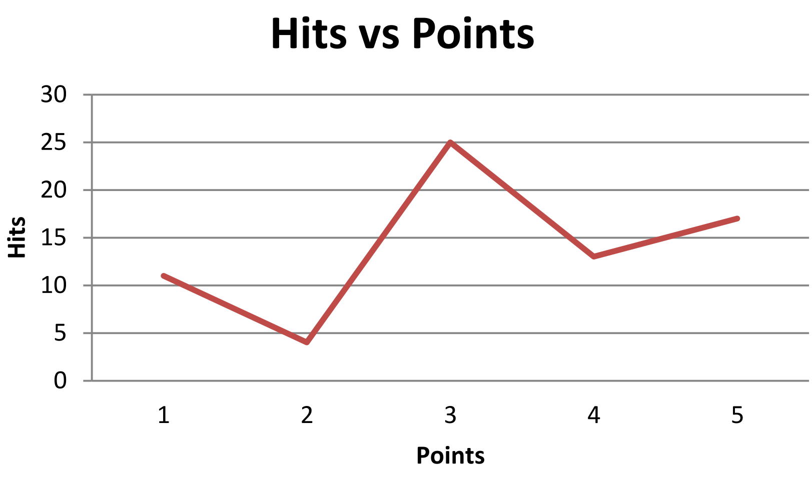

Figure 4.6: Graph hits versus point for non-defected welding joint

Table 4.3: Number of count for defected and non-defected welding joint at all point

	Experiment 1	***Experiment 2***
Point	**Number of Counts**	**Number of Counts**
1	48	20
2	50	25
3	67	46
4	24	22
5	33	21

The number of counts is refer to number of times the signal crosses the threshold level. In AE signal analysis, threshold voltage level is generally set to distinguish signal from noise. An AE event is counted just only if the signal crosses the threshold level. In both experiment one and two, the threshold level was set to 0.01V.

From the table above, the number of counts for defected welding joint slightly higher compared to the non-defected joint at all point. Again, the trend of counts were similar like previous parameters where the highest number occur at defected joint. This condition will strongly support that the source of the acoustic emission signals was from the defected welding joint.

Same like previous parameter, the AE signatures produces when local dynamic movements such as initiation and propagation of cracks, twinning, slip dislocation movements, phase transformation and fusion disturbed the material composition and release the energy. The energy released travels as a spherical wave front and is converted as electrical signal by transducers placed on surface of the material and this signal called as AE signal.

From the data taken the number of counts highest at third position for both defected and non defected welding joint. This condition occur shows that the original sources of the acoustic emission signals was from the load that hung near the third position of joint.

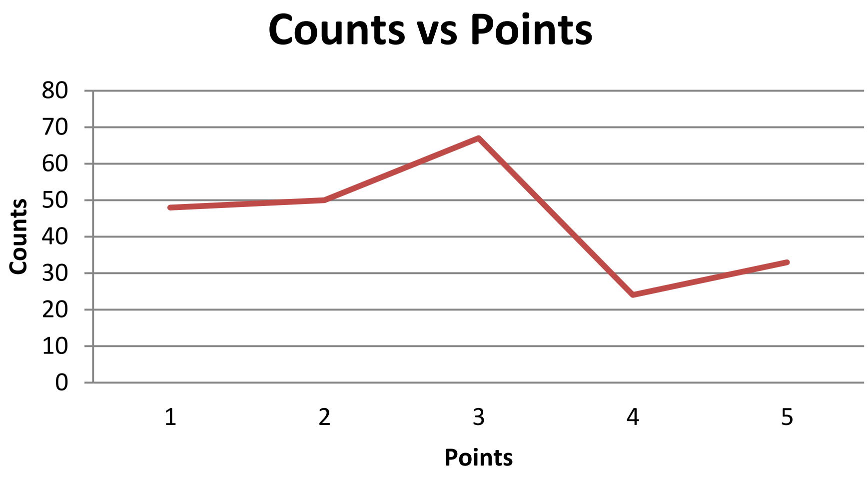

Figure 4.7: Graph counts versus point for defected welding

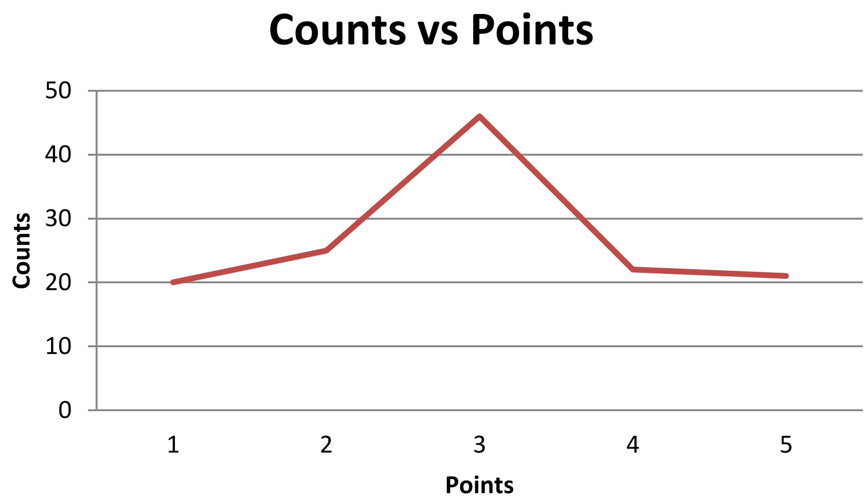

Figure 4.8: Graph counts versus points for non-defected welding joint

Table 4.4: Peak amplitude value for defected and non-defected welding joint at all point

	Experiment 1	*Experiment 2*
Point	**Average Peak Amplitude**	**Average Peak Amplitude**
1	0.063812257	0.056732177
2	0.140319825	0.103378295
3	0.167453632	0.149867123
4	0.157623291	0.050933837
5	0.082366943	0.034881592

Table 4.4 above show the value for average peak amplitude for defected and non-defected welding joint at all point. Peak amplitude refer to the highest amplitude attained by signal in an event. After some analysis by using Matlab software, the trend of peak amplitude still show similar result like number of hits and counts. The value of average peak amplitude for defected joint was higher compared to the peak amplitude value for non-defected joint. The highest value also still occur at third position similar to the number of counts that already describes before.

Defected joint will generated stress wave that caused by rapid release of energy within a material during plastic deformation, crack initiation and crack growth. An acoustic emission sensor (usually piezo-electric based) in contact with the welding joint, detects the mechanical shock wave and converts the very low displacement, and high frequency mechanical wave, into an electronic signal that is amplified by a preamplifier and processed by the AE instrument. That is why the peak amplitude of defected joint was higher compared to the non-defected one. The same theory was used to described the highest value of peak amplitude at third position for both two experiment.

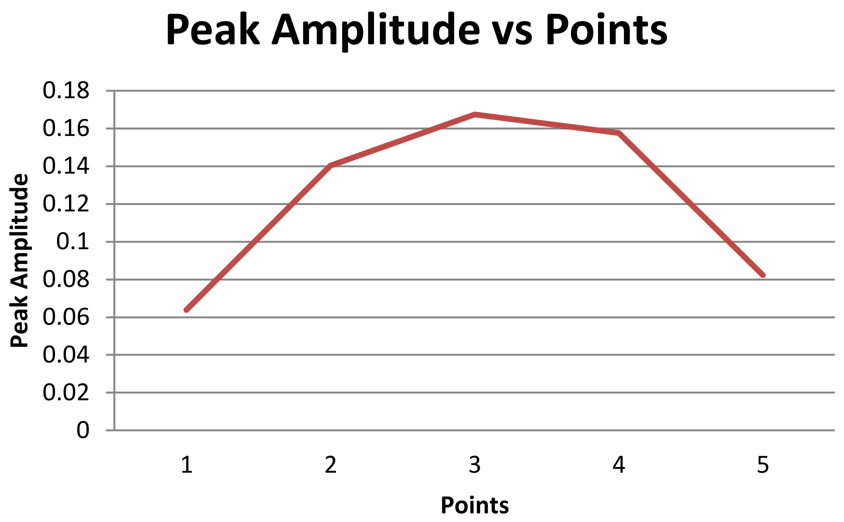

Figure 4.9: Graph peak amplitude versus point for defected welding joint

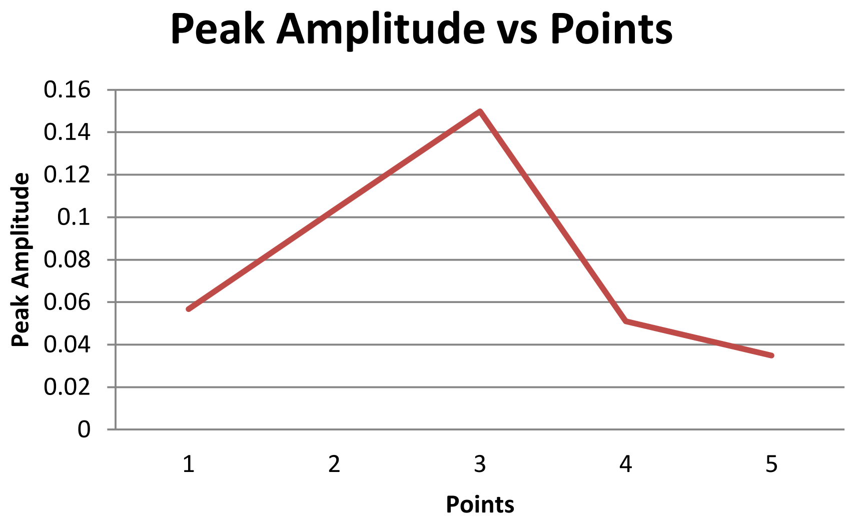

Figure 4.10: Graph peak amplitude versus point for non-defected welding joint

Table 4.4: Average RMS value for defected and non-defected welding joint at all point

	Experiment 1	***Experiment 2***
Point	**Average RMS**	**Average RMS**
1	0.010423918	0.009209003
2	0.025266528	0.011439211
3	0.045674741	0.023543114
4	0.021314337	0.010563898
5	0.020705557	0.00656815

In both experiment one and two, the value of RMS was collected to see the different characters between defected and non-defected welding joint. From hundreds data taken from experiment, only average RMS was analyze to see the signal pattern at welding joint. The maximum average RMS was occur at point 3 on defected welding joint that was 0.045674741 V. Note that the load was hung near the third position and that is the reason why RMS occur highest at this point.

Although the same load was used for all position, but the value of average RMS was not same at all. From the graph below, the average RMS for defected welding joint was higher compared to the non-defected welding for all point. This phenomenon was similar as the previous case where the AE signal occurs high at defected welding joint. AE signatures produces when local dynamic movements such as initiation and propagation of cracks, twinning, slip dislocation movements, phase transformation and fusion disturbed the material composition and release the energy. The energy released travels as a spherical wave front and is converted as electrical signal by transducers placed on surface of the material and this signal called as AE signal.

From the table above, the RMS value for non-defected welding joint was almost zero for all five point. That is because, this type of joint produced lower number of AE signal. The lower number of AE signal shows that the material composition not disturbed by any kind of stress waves.

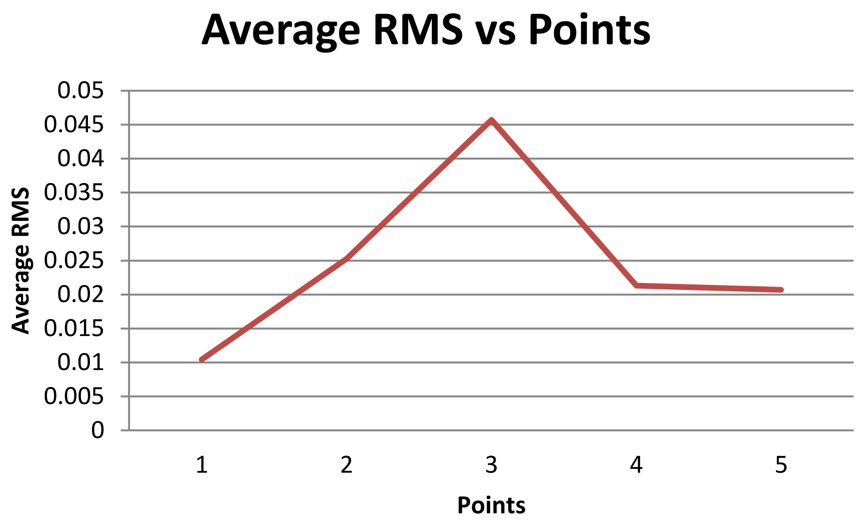

Figure 4.11: Average RMS versus point for defected welding joint

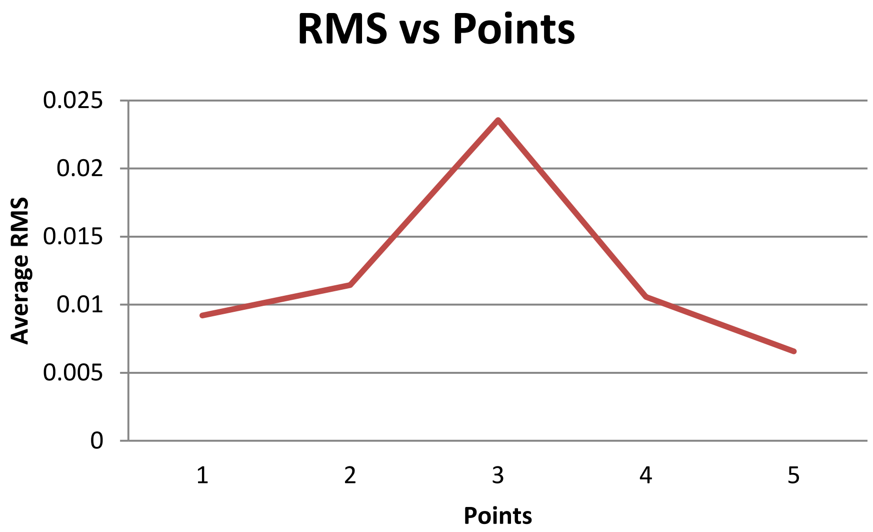

Figure 4. 12: Average RMS versus point for non-defected welding joint

4.7 BEST SIGNAL ANALYSIS BY POINT

4.7.1 Signal character analysis for point 1

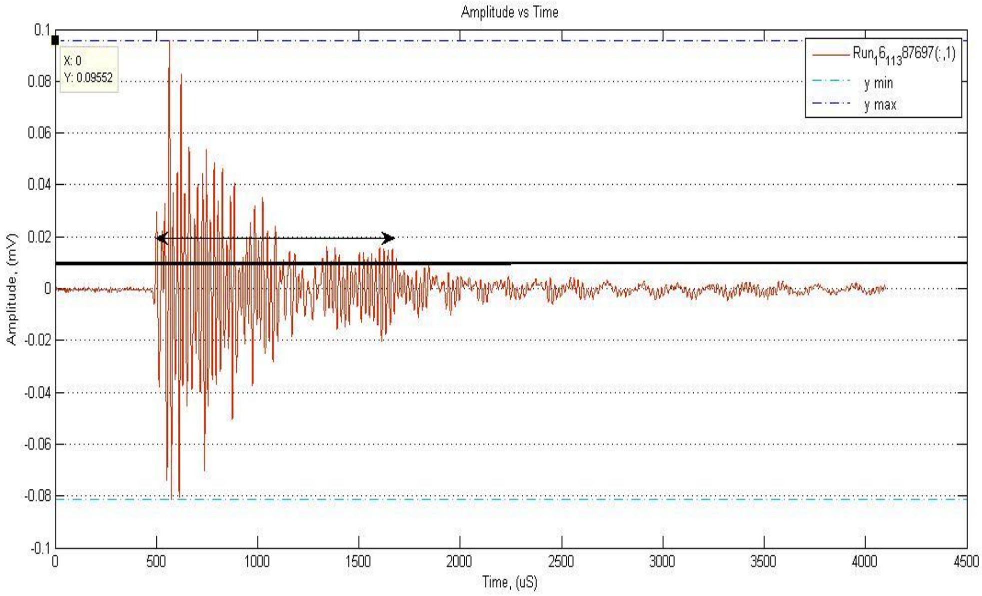

Figure 4.13: Amplitude versus time graph for defected welding joint for point 1

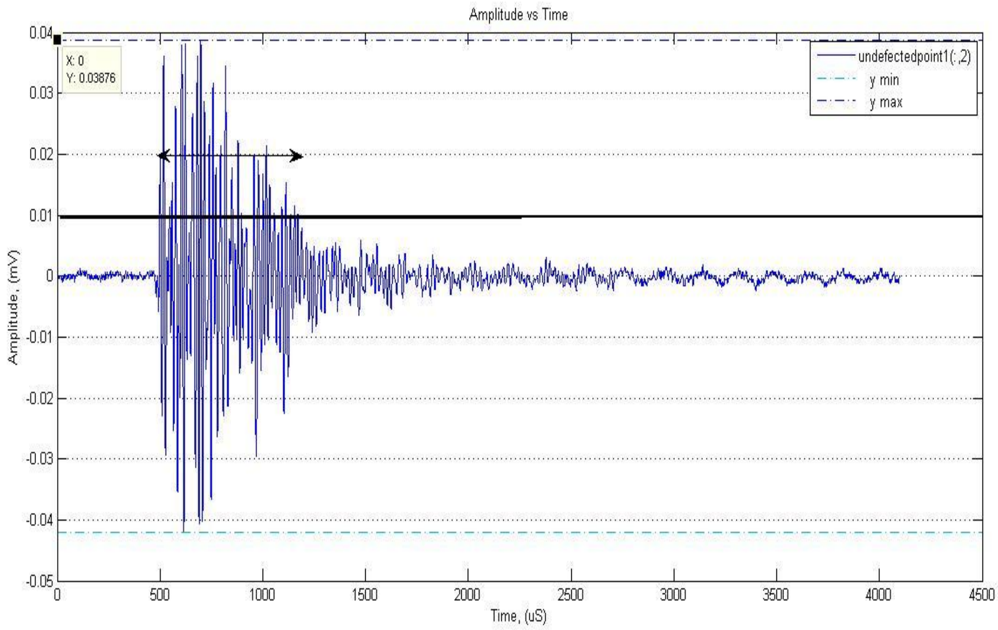

Figure 4.14: Amplitude versus time for non-defected welding joint for point 1

Both graphs above occur after the data taken at point one was analysed using Matlab software. Four signal characteristic were compared between two above figure. Figure 4.13 show the AE waves for defected welding joint meanwhile figure 4.14 show the AE waves for non-defected welding joint.

From the graph, the maximum amplitude that also known as peak amplitude was higher for defected welding joint which is 0.09552 mV. For non-defected welding joint, the value of peak amplitude was 0.03876mV. Signal from strong sources in short distance can give the higher value of amplitude due to the stress or crack that occurs in material composition. Because of this reason, the value of peak amplitude for defected AE sources higher that the non-defected one.

Beside the determination of peak amplitude, another signal characters like numbers of counts also important in AE data analysis. Number of counts also can be described as number of threshold line crossing. From figure 4.13, number of threshold crossing was 48 meanwhile for figure 4.14 was 30. Similar as the peak amplitude, the number of counts for defected welding joint was higher compared to the number of counts for non-defected welding joint data.

The double arrow from both graphs show the signal duration for AE signal. Signal duration was determined by measuring the time from first threshold crossing until the last threshold crossing. For figure 4.13 the signal duration was 1200 μs and for figure 4.14 the signal duration was 800 μs. In this case, the signal duration was different for both graphs because of waveform that cause by stress generation. The defected welding joint takes more time to end the signal duration due to number of waveform occur.

Another parameter that needs to consider in AE data analysis is rise time duration. As mentioned before, rise time was determined by measuring the time between first threshold and the peak amplitude. Both figure above have different rise time duration depend on test properties. The rise time for defected waveform was 80 μs meanwhile for non-defected one the rise time was 110 μs.

4.5.2 Signal character analysis for point 2

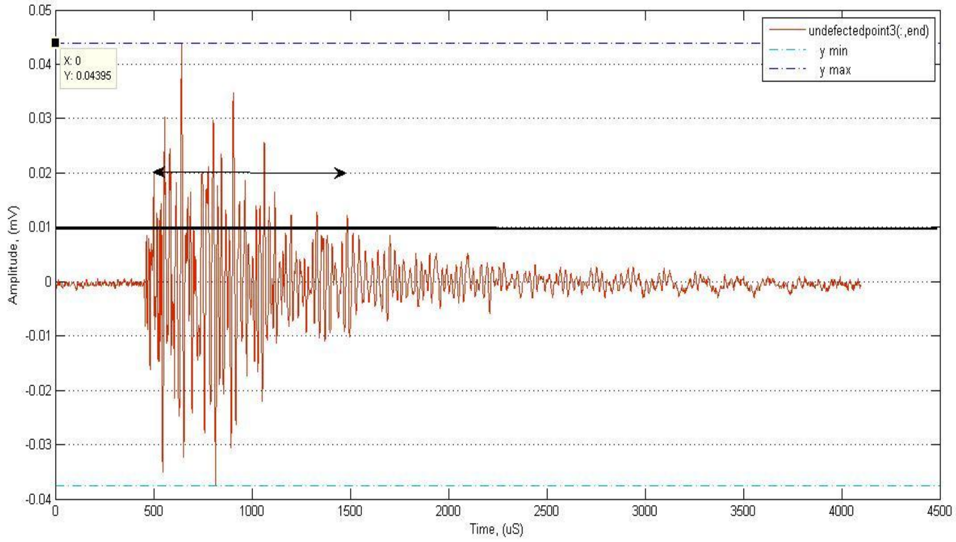

Figure 4.15: Amplitude versus time graph for defected welding joint for point 2

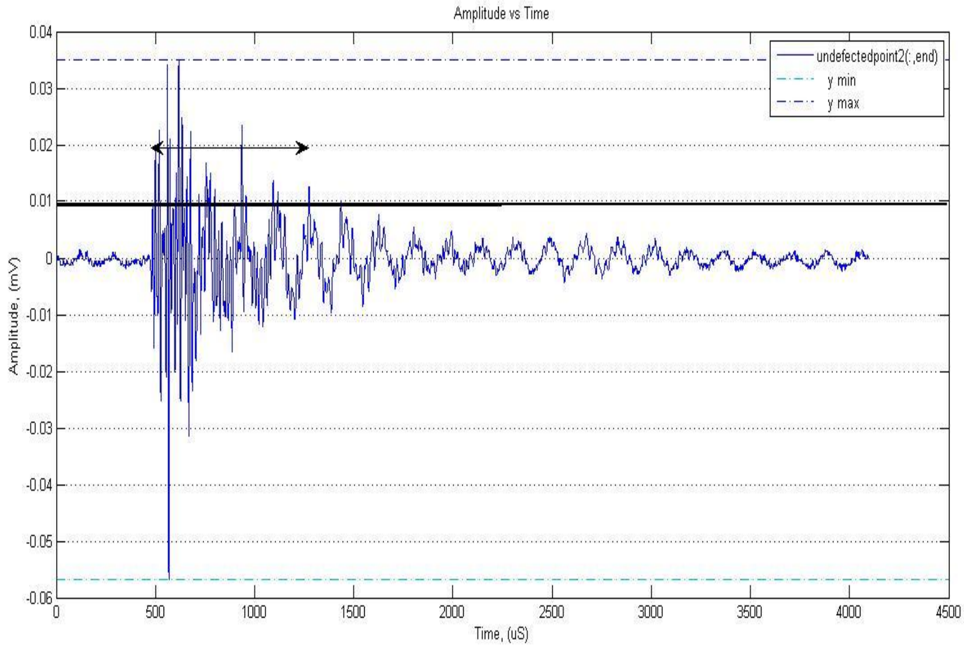

Figure 4.16: Amplitude versus time graph for non-defected welding joint for point 2

Figure 4.15 and figure 4.16 show the AE trend for defected welding joint and non-defected welding joint for second position. For second position, the sensor was placed 30 mm from the first position. In order to analyse the AE wave for second position, all four parameters that already discussed above need to explain for a second time.

Peak amplitude for defected welding joint for second position was 0.04265mV. The peak amplitude becomes 0.03456mV when the sensor was attached to the non-defected welding joint. From the both graphs above, the peak amplitude for defected welding joint slightly higher than the peak amplitude for non-defected joint

After the analysis of the peak amplitude, number of counts need to calculated. Number of counts that occur for defected welding joint was 20 and it becomes 15 when the sensor was attached to the non-defected welding joint. From the value of count that has been calculated above, the different data occur was caused by stress at joint.

Beside the peak amplitude and number of counts, other parameters that was analysed was signal duration. As mentioned before, signal duration was the time where the wave crossing the first threshold until it touched the last threshold. The signal duration for defected welding joint was 1000 µs meanwhile for non-defected welding joint; the signal duration was 850 µs. Again, the parameters show the unwanted characteristics where the signal duration for defected welding joint lowers than non-defected one. The duration was depends on source magnitude and noise filtering so than the duration for defected welding joint should be longer compared to the non-defected one.

Another parameter that involved in AE data analysis was rise time. Rise time is a time interval between the triggering time of AE signal and the time of peak amplitude was assigned. The rise time for defected welding joint was around 250 µs meanwhile for non-defected welding joint was around 200 µs. The rise time show correct character because rise time was applied to eliminate noise signals.

4.5.3 Signal character analysis for point 3

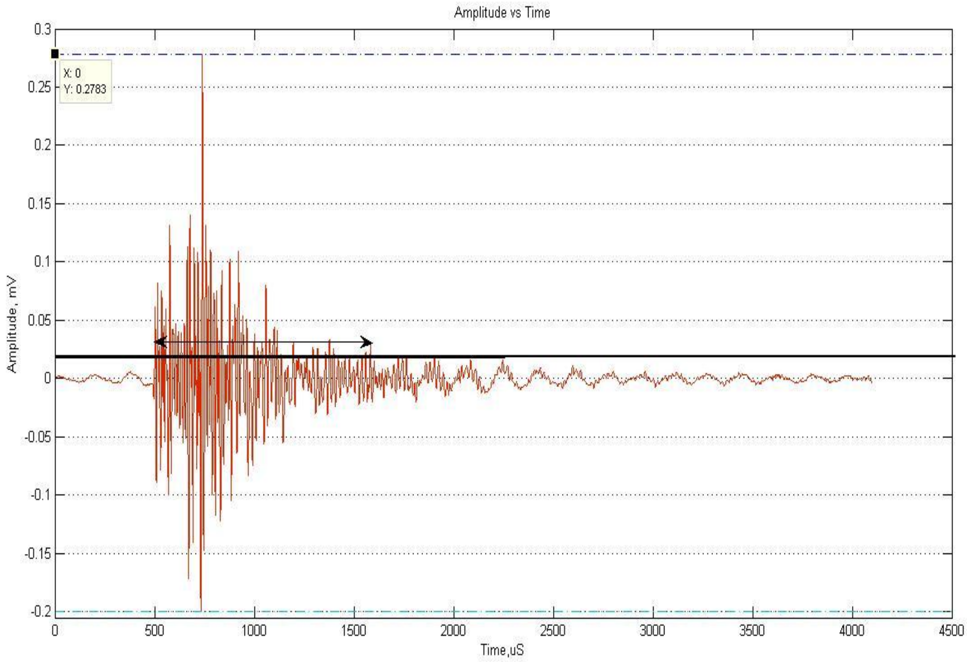

Figure 4.17: Amplitude versus time graph for defected welding joint for point 3

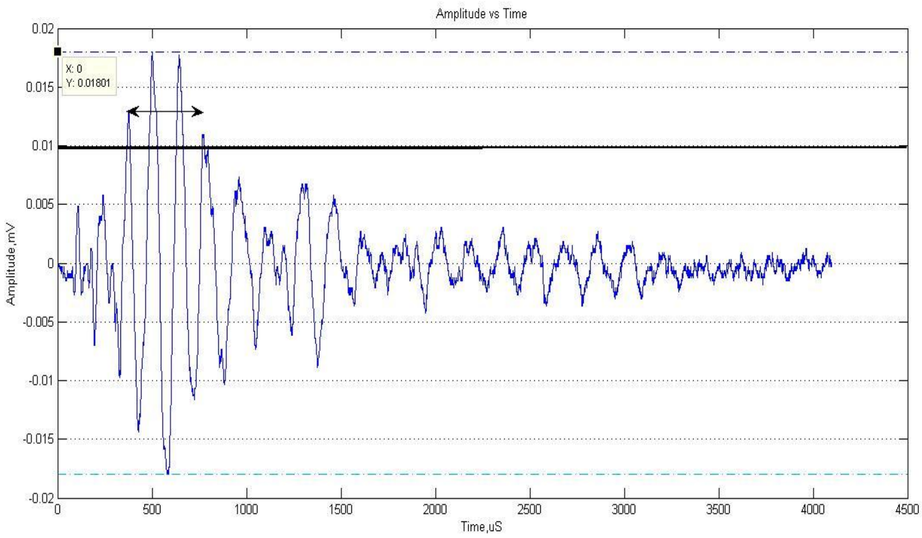

Figure 4.18: Amplitude versus time for non-defected welding joint for point 3

Both figure 4.17 and figure 4.18 were constructed for the third position where the sensor was attached. For third position, the sensor was located at the middle of welding joint. The same procedure was applied for third position where four data signal need to analyse.

The first parameter was peak amplitude. The peak amplitude for figure 4.17 was 0.01801mV. Figure 4.17 was constructed to show the AE trend for defected welding joint meanwhile Figure 4.18 for non-defected welding joint. Peak amplitude that occurs for non-defected welding joint was 0.04395mV and again the value is lower compared to the defected joint.

To continue the data analysis of AE signatures, a set of data was need to construct the count. The count was the number of times within the duration where one signal exceeds a present threshold. Because of the set of data was disturbed by unwanted signal, the number of counts that occurs for defected welding joint was lower compared to the non-defected welding joint. In figure 4.17, 30 counts are observed meanwhile only four counts are observed in figure 4.18. Counts also employed to quantify the AE activity as well as hit. The higher different number of count at this point was cause by weight of load that hung near with this position number three.

For signal duration, the longer time of duration show the big source magnitude. It is mean that the bigger source magnitude, so the signal duration will run in a long period of time. In this case the signal duration for defected welding joint was around 1250 µs meanwhile for non-defected joint; the signal duration was 200 µs.

4.5.4 Signal character analysis for point 4

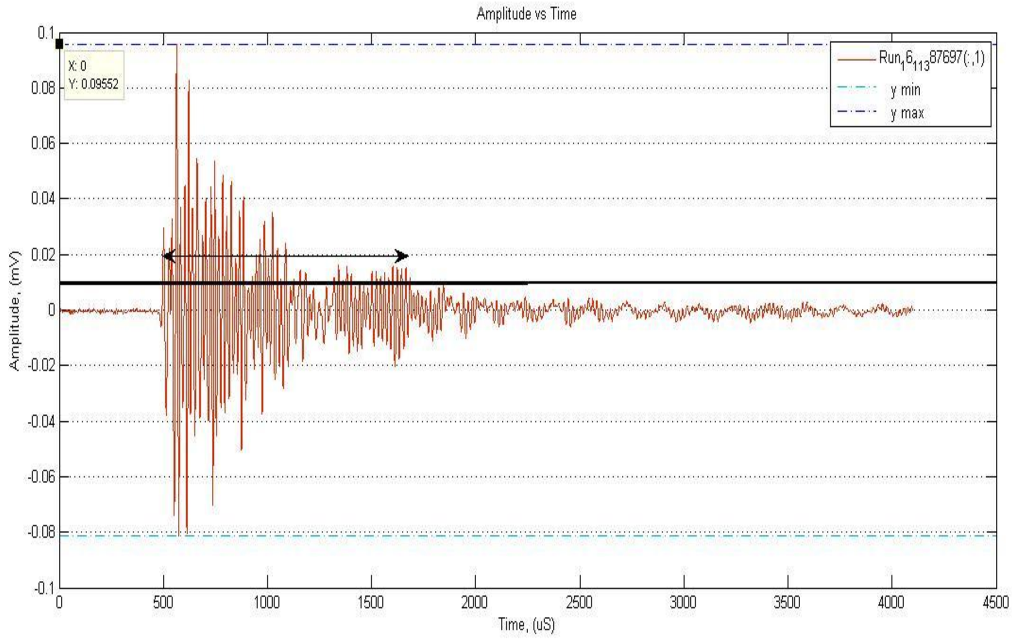

Figure 4.19: Amplitude versus time graph for defected welding joint for point 4

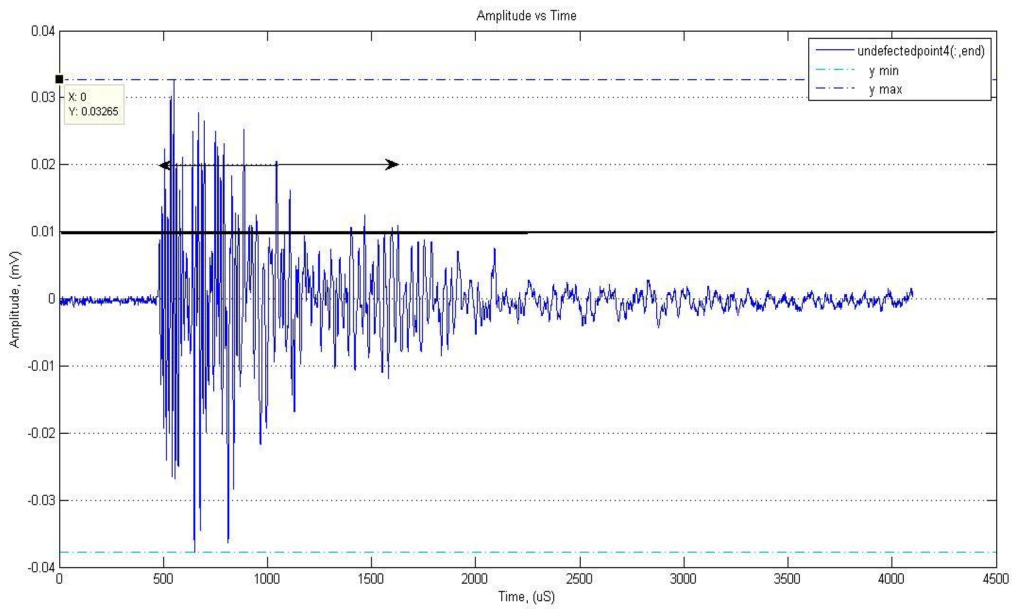

Figure 4.20: Amplitude versus time graph for non-defected welding joint for point 4

Both figure 4.19 and figure 4.20 show the signal characteristics for position number four on welding joint. Position number four was located 30mm from position number three and the sensor was sense the signal or waveforms that occur at this position. Same procedure like previous point, four signal characters was defined for both experiment one and two. Experiment one was conducted to saw the signal characters of defected welding joint meanwhile the second experiment was conducted to saw the signal character on non-defected welding joint.

The first parameters that need to describe was peak amplitude. Peak amplitude was defined as one of the important burst features. Crack signals show medium to high amplitudes and have durations of some microsecond depending on the test object's properties. Peak amplitude for figure 4.19 was 0.0415 mV. This peak amplitude was higher that the peak amplitude for figure 4.20 which is 0.03265 mV. As mentioned before the higher value of peak amplitude show the crack occurs at this location.

Beside determination of peak amplitude value, the number of counts also important in AE wave analysis. The number of counts for figure 4.19 was 24 meanwhile for figure 4.20 the number of counts occur was 21. The different number of count can proved at which location actually the stress generate in large number so we can decided either that location was defected or not.

For signal duration, the longer time of duration show the big source magnitude. It is mean that the bigger source magnitude, the signal duration will run in a long period of time. In this case the signal duration for defected welding joint was around 1200 µs meanwhile for non-defected one; the signal duration was 900 µs. In both figure above, signal duration was ticked by double arrows.

Another parameter that needs to consider in AE data analysis is rise time duration. As mentioned before, rise time was determined by measuring the time between first threshold and the peak amplitude. Both figure above have different rise time duration depend on test properties. The rise time for defected waveform was 80 µs meanwhile for non-defected one the rise time was 60 µs.

4.5.4 Signal character analysis for point 5

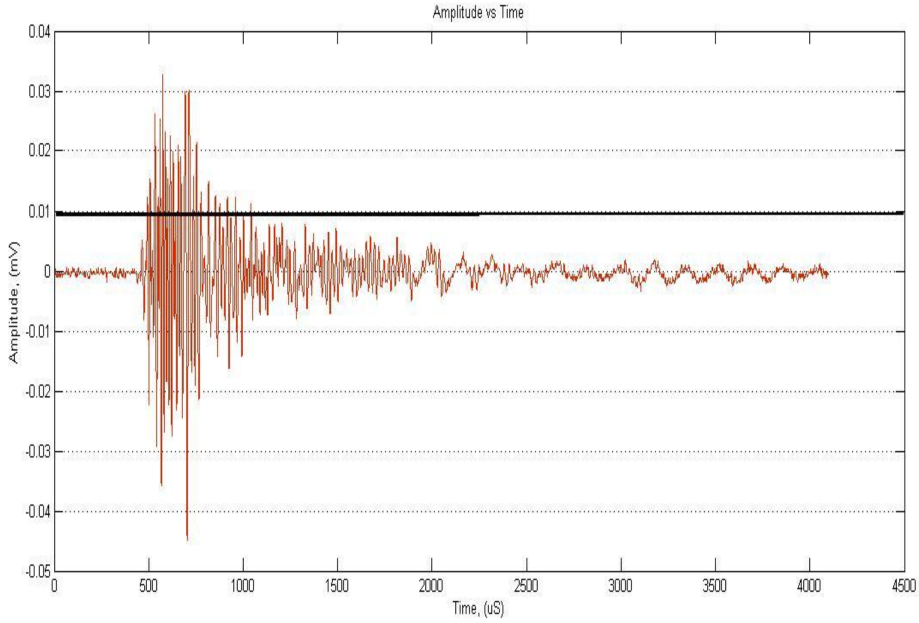

Figure 4.21: Amplitude versus time graph for defected welding joint for point 5

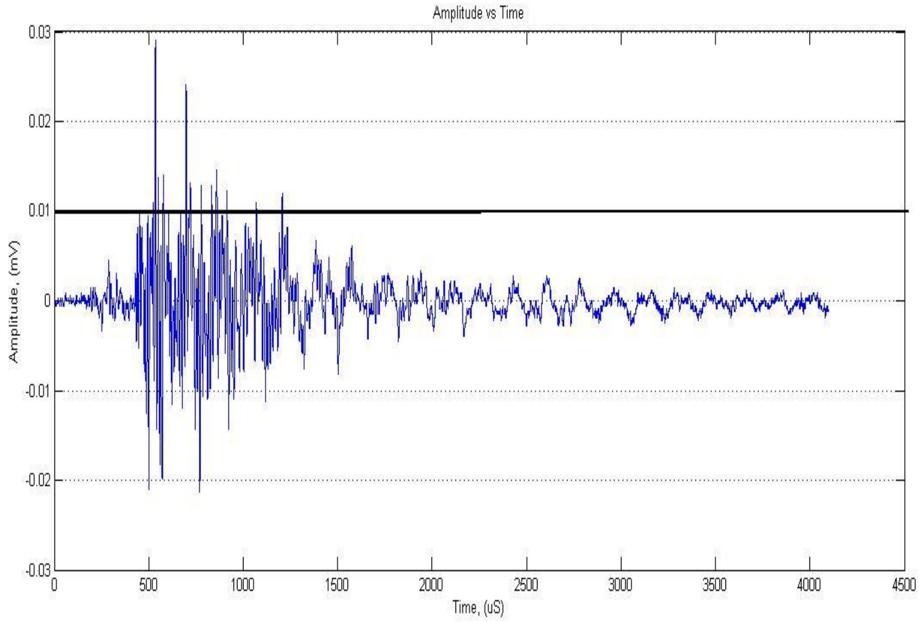

Figure 4.22: Amplitude versus time graph for non-defected welding joint for point 5

Both graphs above occur after the data taken at point five was analysed by using Matlab software. Four signal characteristic were compared between two above figure. Figure 4.21 show the AE waves for defected welding joint meanwhile figure 4.22 show the AE waves for non-defected welding joint.

From the graph, the maximum amplitude that also known as peak amplitude was higher for defected welding joint which is 0.0334 mV. For non-defected welding joint, the value of peak amplitude was 0.02876mV. Signal from strong sources in short distance can give the higher value of amplitude due to the stress or crack that occurs in material composition. Because of this reason, the value of peak amplitude for defected AE sources higher that the non-defected one.

Beside the determination of peak amplitude, another signal characters like numbers of counts also important in AE data analysis. Number of counts also can be described as number of threshold line crossing. From figure 4.21, number of threshold crossing was 30 meanwhile for figure 4.22 was 21. Similar as the peak amplitude, the number of counts for defected welding joint was higher compared to the number of counts for non-defected welding joint data.

Signal duration was determined by measuring the time from first threshold crossing until the last threshold crossing. For figure 4.21 the signal duration was 530 µs and for figure 4.22 the signal duration was 520 µs. In this case, the signal duration was different for both graphs because of waveform that cause by stress generation. The defected welding joint takes more time to end the signal duration due to number of waveform occur.

Another parameter that needs to consider in AE data analysis is rise time duration. As mentioned before, rise time was determined by measuring the time between first threshold and the peak amplitude. Both figure above have different rise time duration depend on test properties. The rise time for defected waveform was 100 µs meanwhile for non-defected one the rise time was 20 µs.

CHAPTER 5

CONCLUSION

5.1 INTRODUCTION

This chapter wills summary all the result that was collected on the previous chapter and will be evaluate. Suggestion will be make to improve the effectiveness of using acoustic emission testing on Mild Steel (MIG) welding.

5.2 CONCLUSION

This study had proved that the acoustic emission (AE) technique not really acceptable in investigating acoustic emission signal characteristic on welding joint of mild steel. The technique need to be improved in other to ensure it approach some requirement for used in acoustic emission analysis.

From this project, AE signal were started to propagate when the weight was attached at the end of the welding joint of mild steel. The signal characteristics between defected and non-defected welding joint show unfriendly result. The value of peak amplitude, number of hits, and number of counts, signal duration and rise time duration supposed to be a medium to different characteristic between defected welding joint with non-defected joint.

The weight used in both experiment was in constant value which is 40N and was attached at the one side of welding joint. The weight is an important parameter because it linear propagates with wave produce. The higher values of weight produced a higher number of waves. That is the reason why the values of weight not change for all experiment to see the different characters between defected welding joint compared to the non-defected joint.

From the result occur, the value of count, hits, peak amplitude and RMS show the expected result. For every point, the value for every parameters of defected welding joint always higher compared to the non-defected one. This phenomenon clearly show that a lot of AE waves occur on defected welding joint due to growth of cracks. On the other side, the value for all four parameters always higher at position number three for both defected and non-defected joint. This condition show the weight of load produce higher number of acoustic waves. From this research, we can clear say that Acoustic Emission testing was acceptable to be used in welding fault detection.

5.3 RECOMMENDATION

The result for both experiments was based on only five points for every single of test. The result may be dissimilar if more points were used but with little different. Further study needs to be done for more data and having more variety of weight that should be tested. Another recommendation is by do the AE test just after welding process is done. This is an important point because AE waves occur when stress is propagated. When the welding process was done, the number of stress is higher due to growth of cracks.

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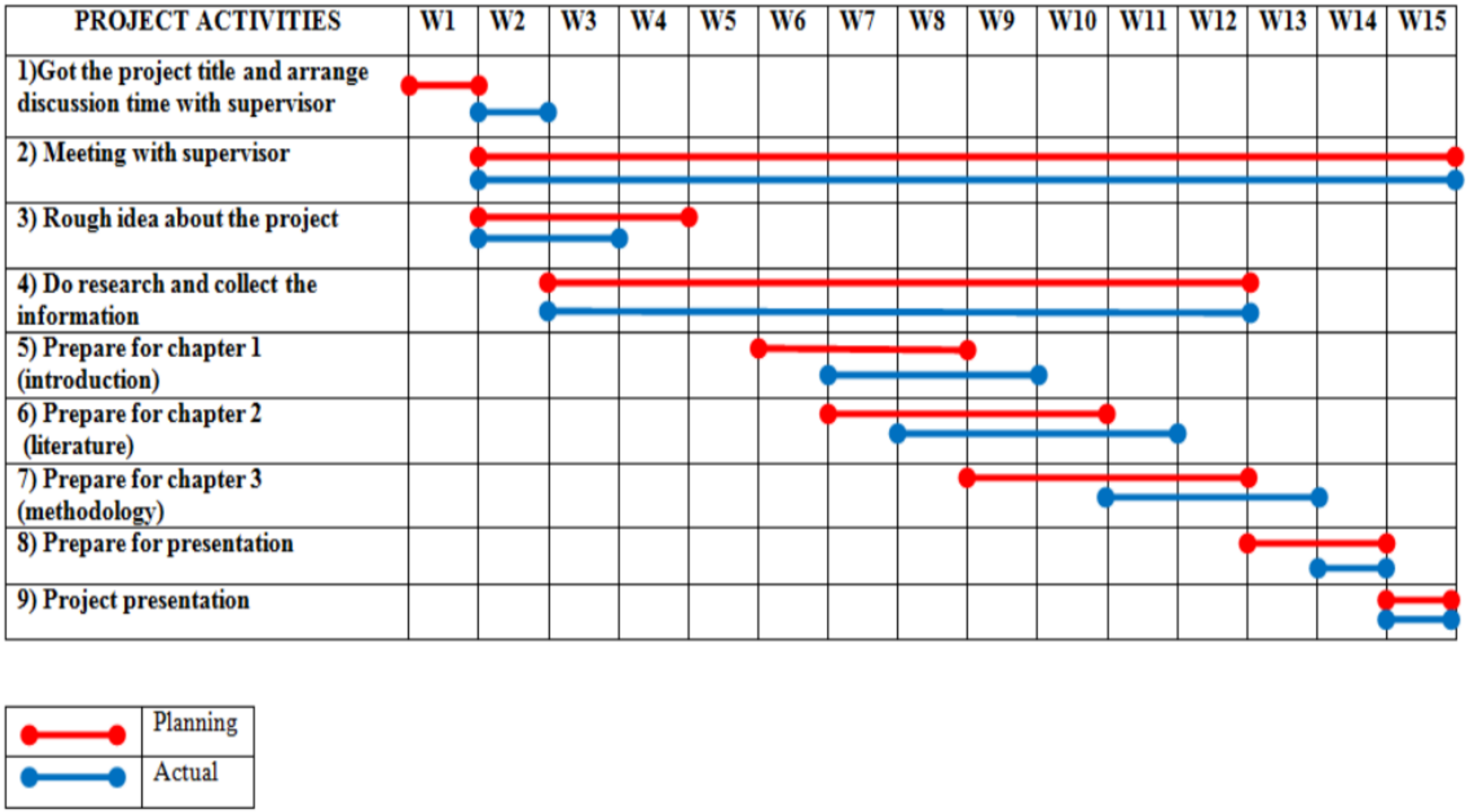
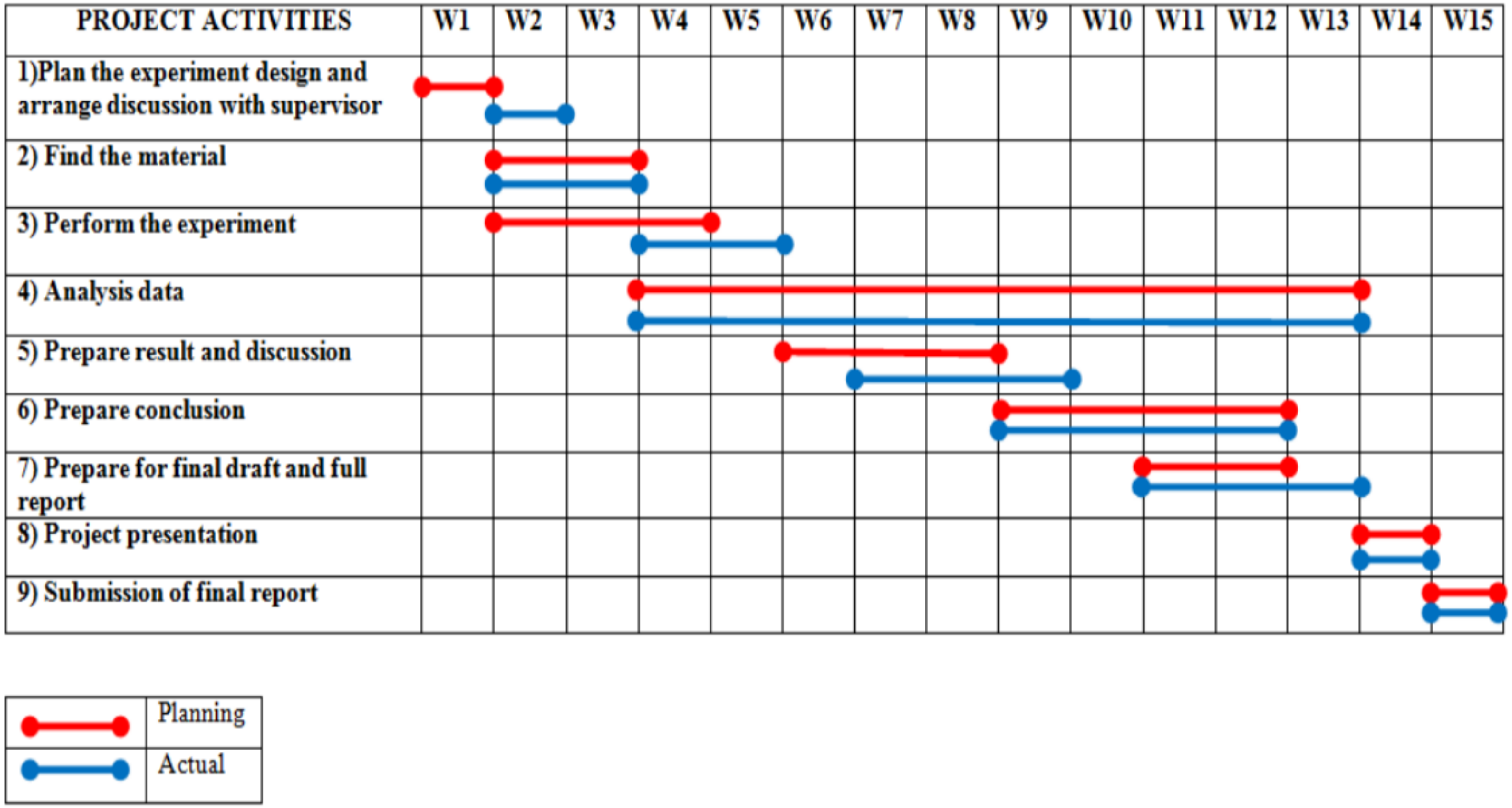
APPENDIX A1

Gantt chart for Final Year Project 1

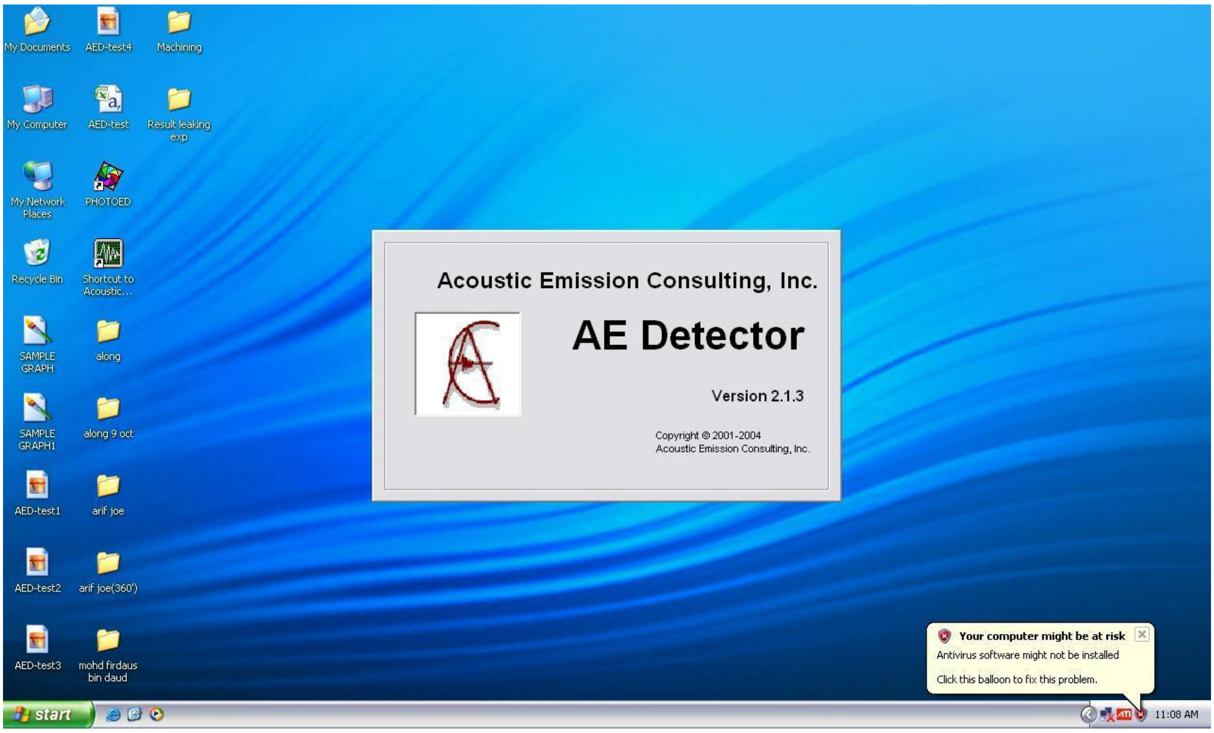


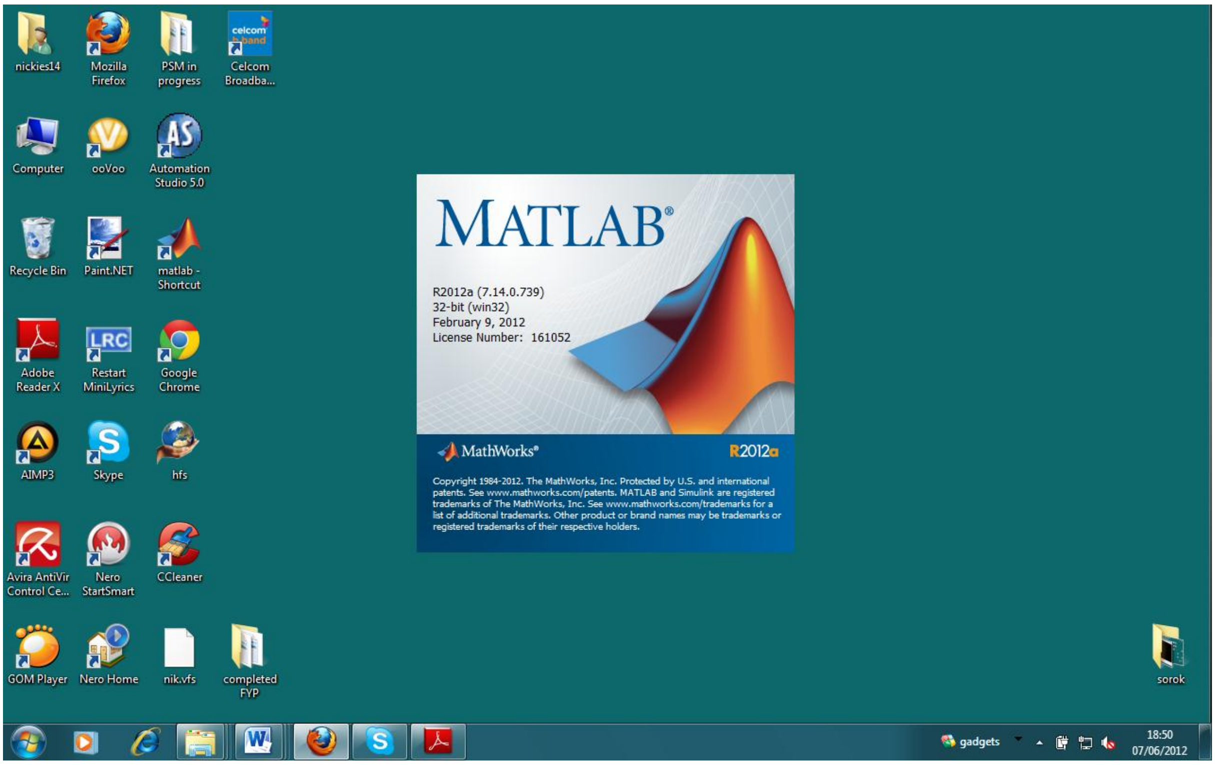
Gantt chart for Final Year Project 2

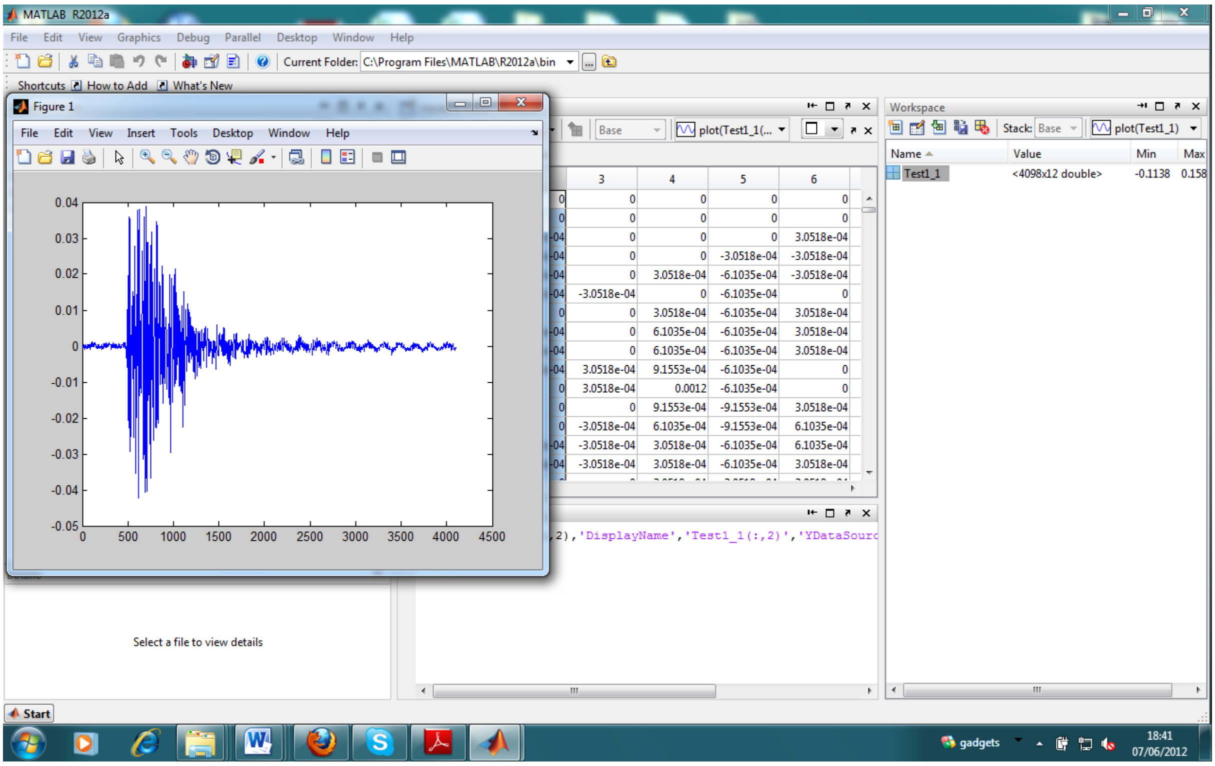


APPENDIX A2

Mode setup applied for Acoustic Emission Detector and Matlab



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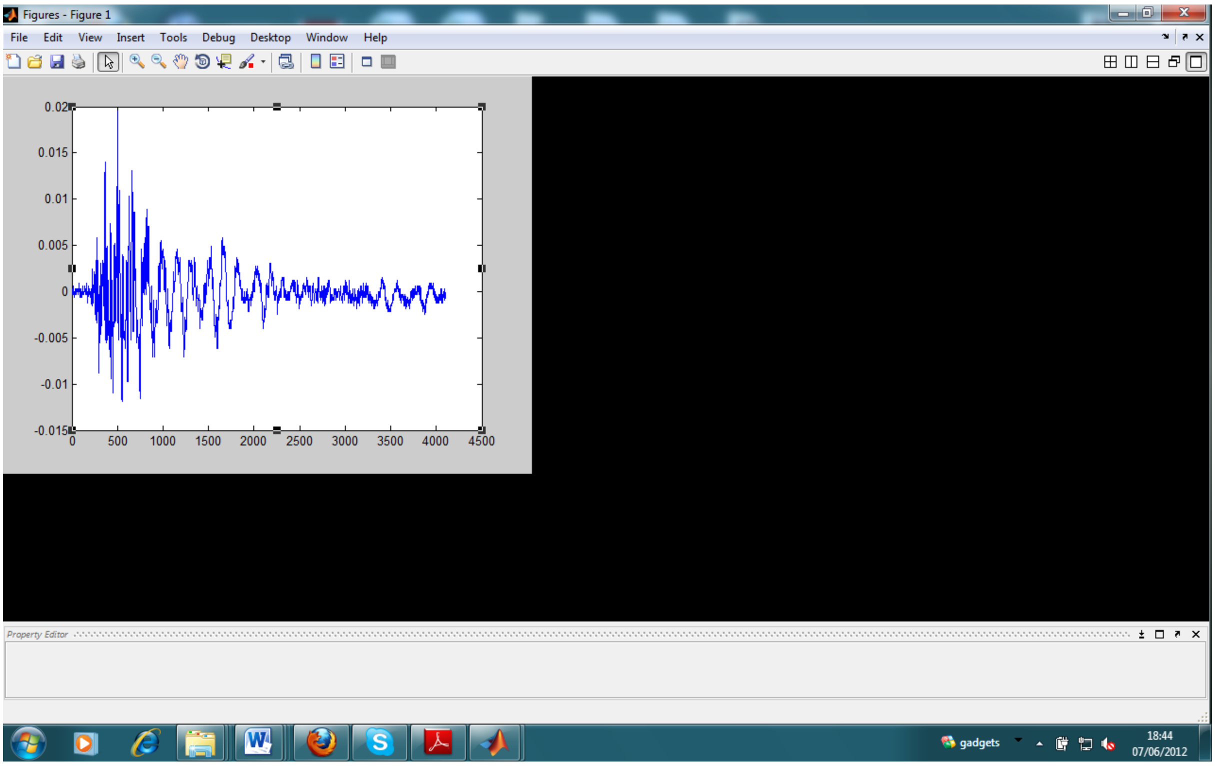
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APPENDIX A3

The example of data analyze by Matlab software for defected and non defected joint

Defected

Point 1

File	RMS	Peak Amplitude	Kurtosiscal	Skewness
1	0.011686525	0.09552002	18.60761913	0.045517141
2	0.009892344	0.04730225	8.022266278	-0.0398541
3	0.006269442	0.01953125	3.133310533	0.087111638
4	0.005247011	0.02593994	6.510830585	-0.020390441
5	0.012814613	0.07080078	8.617512459	0.073080745
6	0.002634766	0.02349854	21.91285278	-0.056224629
7	0.003535964	0.02044678	9.054937596	-0.266054814
8	0.026555705	0.22216797	21.66303384	0.382540284
9	0.021968054	0.09918213	5.817897394	0.03504417
10	0.003634761	0.01373291	8.717918432	-0.387480668

Point 2

File	RMS	Peak Amplitude	Kurtosiscal	Skewness
1	0.04642996	0.24078369	11.66555857	-0.141877272
2	0.11261166	0.67230225	14.07796101	-0.215958214
3	0.004162255	0.03265381	18.31620192	0.49491053
4	0.009461478	0.06408691	16.34122184	-0.174076493
5	0.020511533	0.11260986	3.804143641	0.171674412
6	0.021921662	0.09857178	5.08512828	0.284524272
7	0.00576911	0.03723145	17.54530911	-0.621135282
8	0.004495029	0.02502441	6.106215507	0.151954226
9	0.005174666	0.027771	9.360308335	0.100657796
10	0.022127923	0.09216309	8.176902686	-0.295653211

Point 3

File	RMS	Peak Amplitude	Kurtosiscal	Skewness
1	0.005052874	0.01983643	6.618936403	-0.117341082
2	0.004795392	0.02258301	9.143002358	0.211397193
3	0.020319929	0.07110596	4.071402965	0.322921377
4	0.010558362	0.05096436	9.840957033	-0.041375871
5	0.02074785	0.078125	5.812433875	0.126905747
6	0.004666702	0.01922607	4.545161978	0.204666826
7	0.019572096	0.08239746	4.802866516	0.254250132
8	0.016122101	0.08911133	11.28624736	-0.500760871
9	0.003637558	0.0189209	9.699260742	-0.097697531
10	0.009000463	0.03295898	5.192648661	-0.163734309

Point 4

File	RMS	Peak Amplitude	Kurtosiscal	Skewness
1	0.002906152	0.02685547	21.76257396	0.582344893
2	0.037515976	0.3225708	28.08936481	-0.087012884
3	0.030743923	0.21270752	21.09201951	0.252186716
4	0.005423359	0.04150391	21.95290951	-0.443602663
5	0.012499459	0.07324219	22.17487415	-0.627125306
6	0.064219423	0.45257568	15.67130173	0.153525225
7	0.013607618	0.10009766	14.94251149	0.387063802
8	0.010148871	0.07720947	27.48911626	0.377920948
9	0.003487414	0.02593994	20.99390105	-0.340206369
10	0.032591177	0.24353027	16.49345581	0.291290515

Point 5

File	RMS	Peak Amplitude	Kurtosiscal	Skewness
1	0.007299995	0.02410889	4.601702182	-0.067970832
2	0.099678386	0.29693604	4.369282284	-0.102108852
3	0.003793967	0.03662109	34.04214304	0.406003098
4	0.038013477	0.19805908	6.301672918	0.141177577
5	0.003954542	0.0201416	5.402514131	0.242890051
6	0.002217859	0.01983643	32.14247841	-0.231974648
7	0.006053491	0.02380371	5.056079921	-0.056395121
8	0.027718137	0.10101318	5.300434673	-0.057781483
9	0.002570679	0.02075195	15.35162819	0.242504961
10	0.015755036	0.08239746	7.265242014	-0.349819883

Non- defected

Point 1

File	RMS	Peak Amplitude	Kurtosiscal	Skewness
1	0.011852462	0.03356934	3.509284864	0.014994352
2	0.006438356	0.03875732	16.51253573	0.048087042
3	0.012169716	0.09674072	17.2294156	0.410764933
4	0.01875587	0.15808105	17.66233524	0.400595038
5	0.003303912	0.02655029	21.42418891	-0.674441201
6	0.002597691	0.01953125	10.06838752	0.653789802
7	0.007747448	0.027771	3.201447894	-0.181824334
8	0.009320933	0.04608154	6.206306406	0.532367072
9	0.007321736	0.03967285	6.161987248	0.101702717
10	0.012581912	0.08056641	6.444498197	-0.180311466

Point 2

File	RMS	Peak Amplitude	Kurtosiscal	Skewness
1	0.008880814	0.03997803	3.879138653	-0.088241487
2	0.009005382	0.06011963	19.62266302	-0.795234327
3	0.023020101	0.27832031	29.80029472	0.41380466
4	0.004850547	0.03509521	25.32345072	-0.806921173
Average	0.011439211	0.103378295	19.65638678	-0.319148082

Point 3

File	RMS	Peak Amplitude	Kurtosiscal	Skewness
1	0.007753418	0.03204346	0.03204346	-0.068279176
2	0.014724702	0.05554199	0.05554199	-0.079026598
3	0.005674616	0.02716064	0.02716064	-0.211535367
4	0.027773656	0.17089844	0.17089844	0.279145294
5	0.005467214	0.0201416	0.0201416	0.033815279
6	0.006632517	0.03631592	0.03631592	-0.153195509
7	0.007786916	0.02990723	0.02990723	0.005095626
8	0.00649465	0.01922607	0.01922607	0.02775204
9	0.007733684	0.03234863	0.03234863	0.135713821
10	0.010477385	0.0302124	0.0302124	-0.103186252

Point 4

File	RMS	Peak Amplitude	Kurtosiscal	Skewness
1	0.016590612	0.04241943	3.250019164	-0.020767325
2	0.01569475	0.05767822	3.586799064	0.028361523
3	0.005114021	0.02227783	6.694056267	0.071953016
4	0.028147969	0.1272583	5.699238992	-0.045576172
5	0.004536967	0.02197266	5.380473725	0.013231762
6	0.004229956	0.0189209	4.081903895	0.023708919
7	0.00561927	0.03265381	12.7760909	-0.288455282
8	0.010279358	0.08026123	14.46684746	0.651308902
9	0.012842839	0.08361816	13.8074419	-0.371115577
10	0.002583237	0.02227783	14.32269636	0.114425372

Point 5

File	RMS	Peak Amplitude	Kurtosiscal	Skewness
1	0.007822069	0.03326416	5.737684267	0.491838016
2	0.003269502	0.01922607	7.725487787	-0.028508148
3	0.005413374	0.01861572	2.778471289	0.02473981
4	0.009895222	0.0491333	10.72322416	-0.310476553
5	0.003361943	0.0289917	15.00529896	0.362160283
6	0.006419004	0.03540039	8.289096752	0.004229602
7	0.003807346	0.02258301	10.06765878	0.121705944
8	0.005017755	0.01983643	4.40706574	-0.072422993
9	0.003275814	0.02044678	10.6621544	0.230229981
10	0.017399473	0.10131836	6.308718317	0.126146994