A STUDY OF SURFACE CRACK BEHAVIOUR USING HEAT TREATMENT ON MILD STEEL

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This thesis is submitted in partial fulfillment of the
requirements for the degree of
Bachelor of Mechanical Engineering

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

NOVEMBER 2008

Dedicated to my beloved parent

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SUPERVISOR DECLARATION

“I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering”

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Position :………………………………………
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I declare that this thesis entitled *A study of surface crack behavior using heat treatment on mild steel* is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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ACKNOWLEDGEMENTS

First I would like to express my grateful to ALLAH S.W.T. as for the blessing given that I can finish my thesis.

In preparing this thesis, I have engaged with many people in helping me completing this project. First, I wish to express my sincere appreciation to my main thesis supervisor Mr Mohamed Reza Zalani bin Mohamed Suffian, for encouragement, guidance, advices and motivation. Without his continued support and interest, this thesis would not have been the same as presented here

The next category people who help me to grow further and influence my project are the colleagues who always help me in order to finish this project whatever their affords in helping to finish this thesis. I would like to express my gratitude to the panels that criticize me in order to finishing this thesis. I appreciate very much to them because of the idea and information given.

Last but not least I acknowledge without endless love and relentless support from my family, I would not have been here. Father, mother and sisters, you all have given me the inspirations and encouragement until these days.

Thank you all.

ABSTRACT

In the real industry life, welding is widely used and commonly can be found in any type of industries and the most common welding process is Shield Metal Arc Welding (SMAW). SMAW is used in this study because of the application of this type of welding is widely used and the cost of this welding is cheap. Welding common defect is crack. In order to solve the problem about crack from growing, a study on prevention of the crack is done in this study respected to the heat treatment. Although most of the industries using quenching as the common heat treatment process, the heat treatment itself is still applicable in determining the crack growth. So, the purpose of this study is to search and learn the effectiveness of annealing followed by normalizing in reducing the crack and preventing the crack growth. All specimen is take into consideration as all the specimen have the same crack but different length. First step in the process is to weld the workpiece and then observation is done using microscope to search the crack and mark. Heat treatment is done after marking process and observation at the crack was done to collect the data. Polishing was done after welding and heat treatment to reveal the crack. There is no comparison between the types of heat treatment effectiveness. The percentage of crack that was reduced was 41.1% as average number. Then the data obtained will be analyzed and a study is commencing in heat treatment toward crack growth prevention. At last, the heat treatment can be proving as one of the process for preventing crack other than physical treatment.

ABSTRAK

Di dalam dunia industri, kimpalan selalunya digunakan dan acab kali boleh dijumpai di mana-mana industri dan kimpalan yang selalunya digunakan ialah “Shield Metal Arc Welding (SMAW)”. SMAW digunakan didalam kajian kerana mudah didapati dan juga kurang kos. Kesan sampingan yang selalunya terdapat pada sesuatu kimpalan salah retakan.Dalam usaha untuk mengatasi masalah ini dengan mengurangkan kadar pembetukan retakan, satu penyelidikan telah di buat dia dalam folio ini bersandarkan penggunaan rawatan haba.Walaupun kebanyakan industri menggunakan “quenching” sebagai rawatan haba yang khusus tetapi ini menunjukkan bahawa rawatan haba masih boleh mengurakan kadar pembentukan retakan dia dalam kimpalan. Oleh itu, tujuan penyelidikan ini dijalankan ialah untuk mengenal pasti kadar keberkesanan “annealing” diikuti “normalizing” dalam mengurangkan kadar pembentukan retakan. Ke semua bahan kajian dianggap penting kerana di dalam kajian ini kesemua bahan kajian mempunyai jenis retakan yang sama tetapi panjang yang berlainan. Proses pertama ialah mengimpal dan pemerhatian di buat menggunakan mikroskop untuk mencari retakan dan menandanya. Rawatan haba dijalankan selepas penandaan dibuat dan retakan di perhatikan untuk mencatat data. Penggilapan bahan dijalan selepas kimpalan dan rawatan haba untuk memudahkan retakan di lihat. Tiada perbandingan antara keberkesanan antara rawatan haba dikaji di dalam penyelidikan ini. Peratusan retakan yang dapat di kurangkan ialah sebanyak 41.1% sebagai satu nombor purata. Kemudian kesemua data akan dia analisis dan satu penyelidikan berkenaan rawatan haba terhadap pengurangan pengembangan retakan dijalankan.. Akhir sekali, terbukti bahawa rawatan haba masih mampu mengurangkan kadar pengembangan retakan selain daripada rawatan secara fizikal.

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LIST OF SYMBOLS

% - Percentage

v - Poisson ratio

^{o}C - Temperature

A - Ampere

V - Voltage

ρ - Density

E - Young modulus

D - Diameter

LIST OF ABBREVIATIONS

SMAW	-	-Shield Metal Arc Welding
AC	-	Alternating current
DC	-	Direct current
Mn	-	Manganese
S	-	Sulphur
SEM	-	Scanning Electron Microscope
MMA	-	Manual Metal Arc Welding
GMAW	-	Gas metal arc welding
T	-	Temperature
C	-	Carbon
Max	-	Maximum
HAZ	-	Heat Affected Zone
µm	-	micrometer
mm	-	millimeter

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

In joining process, they involve in various ways to combine between two metals with similar properties or with different properties. One of the processes is through welding process. Welding is most widely utilized as a joining method for steel structures. Weld joints often contains defects such as slag inclusions, incomplete fusion, gas pores, undercuts at weld toes, porosity and underfills. These defects act as stress raisers and cause premature failure of structures.

Welding is one of the types in permanent joining process. This method is widely use in many construction area for example in the port, harbor and automotive factory. Many type of welding was developed to improve weld quality and through that a new improvement product is produce from improved weld quality. In automotive part, almost all of the parts in a car use joining process whether it is welding process. This process is done to join between two metals. The improvement of welding quality is necessary to ensure that the product that was made using this process is safe and secure enough to be use by customer.

1.2 PROBLEM STATEMENT

In the recent development, machine is used to aid us in the welding fields. The major causes that make people or company used automated machine is the product that is going to be produce is a better product and can eliminate the common defects that always happened to human basis work. Overlaps, underfill, slag inclusions, gas pores, corrosion are common types of defects can be found after welding that was conducted by human. There are many type of crack can be determine through the experiment for example longitudinal crack, creep crack, toe crack and transverse crack. The focus of this study is how to improve weld quality before the crack propagate and reduce the percentage of crack from initiated by applying the normalizing at the heat affected zone (HAZ).Scanning electron microscope is going to be use to observed the microstructure and the crack.

1.3 OBJECTIVE OF RESEARCH

a) To improve the weld region by applying heat treatment that is normalizing.
b) To identify the effectiveness of the normalizing towards the crack.
c) To reduce the crack by applying heat treatment that is normalizing.

1.4 SCOPE OF RESEARCH

a) Improve weld quality by applying the heat treatment to the low carbon steel (AISI 1018) using normalizing.
b) Using Shield Metal Arc Welding (SMAW) arc welding to joint between 2 AISI 1018 steel.
c) Using Microscope to observed the crack and states the comparison of crack between before and after heat treatment.

CHAPTER 2

LITERATURE REVIEW

2.1 ARC WELDING

In the joining process, there are three major categories which are welding, adhesive bonding and mechanical fastening. Under the welding category, there are three more sub-categories which is fusion welding, solid-state welding and brazing and soldering. Arc welding fall into one of this type of welding that is fusion welding. Fusion welding is defined as the process that melts materials and coalescing with each other (Serope Kalpakjian et al 2006). Filler material may or may not be used. Arc welding uses a welding power supply to create an electric arc between an electrode and the base material to melt the metals at the welding point.

Arc welding can be used either direct current (DC) or alternating current (AC), and consumable or non-consumable electrodes. Sometimes the welding region is protected by inert or semi-inert gas that is known as a shielding gas, and some of the process might use filler material or not (Serope Kalpakjian et al 2006). In the arc welding, there are some apparatus that must be prepared before welding is constructed. For example in the simple arc welding, the common apparatus that must be prepared are electrodes, power supply, welding helmet for protection from burr and ultraviolet protection.

Figure 2.1: Arc welding

[Taken from Wikipedia:Arc Welding]

2.2 SHIELD METAL ARC WELDING

Shielded metal arc welding (SMAW), also known as manual metal arc (MMA) welding or informally as stick welding, is a manual arc welding process that uses a consumable electrode coated in flux to lay the weld (Serope Kalpakjian et al 2006). An electric current, in the form of either alternating current or direct current from a welding power supply, is used to form an electric arc between the electrode and the metals to be joined. As the weld is laid, the flux coating of the electrode disintegrates, giving off vapors that serve as a shielding gas and providing a layer of slag, both of which protect the weld area from atmospheric contamination. The process is used primarily to weld iron and steels (including stainless steel) but aluminum, nickel and copper alloys can also be welded with this method (Wikipedia: SMAW article, 2008).

2.2.1 Operation

To strike the electric arc, the electrode is brought into contact with the workpiece in a short sweeping motion and then pulled away slightly. This initiates the arc and thus the melting of the workpiece and the consumable electrode, and causes droplets of the electrode to be passed from the electrode to the weld pool. As the electrode melts, the flux covering disintegrates, giving off vapors that protect the weld area from oxygen and other atmospheric gases. In addition, the flux provides molten slag which covers the filler metal as it travels from the electrode to the weld pool. Once part of the weld pool, the slag floats to the surface and protects the weld from contamination as it solidifies. Once hardened, it must be chipped away to reveal the finished weld (Wikipedia: SMAW article, 2008).

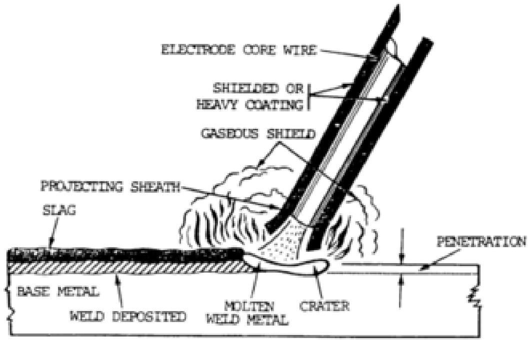


Figure 2.2: SMAW system setup

[Taken from Wikipedia: SMAW article, 2008]

The actual welding technique utilized depends on the electrode, the composition of the workpiece, and the position of the joint being welded. The choice of electrode and welding position also determine the welding speed. Flat welds require the least operator skill, and can be done with electrodes that melt quickly but solidify slowly. This permits higher welding speeds. Sloped, vertical or upside-down welding requires more operator skill, and often necessitates the use of an electrode that solidifies quickly to prevent the molten metal from flowing out of the weld pool. However, this generally means that the electrode melts less quickly, thus increasing the time required to lay the weld (Wikipedia: SMAW article, 2008).

2.2.2 Equipment

Shielded metal arc welding equipment typically consists of a constant current welding power supply and an electrode, with an electrode holder, a work clamp, and welding cables (also known as welding leads) connecting the two.

2.2.3 Power supply

In the welding process, power supply can be classified into two types that are constant current supplies or constant voltage supplies. Commonly, people or professional welder using constant current because of their properties that is easy to automate the current while the voltage varies along the weld plate. In the gas tungsten arc welding and shielded metal arc welding, current constant is used. As discussed above, when the current is steady, the voltage is fluctuating (Wikipedia: SMAW article, 2008).

In the manual arc welding, it is impossible to hold an electrode steadily and this act affect the voltage and the arc length and makes them fluctuate. In the constant voltage power supplies, the principle is against the constant current supply that is the voltage constant and varies the current. Most of the welding that uses this type of power supply is automated type of welding such as gas metal arc welding, flux cored arc welding, and submerged arc welding (Wikipedia: SMAW article, 2008).

Figure 2.3: Power supply

[Taken from Wikipedia: SMAW article, 2008]

The type of current used in arc welding also plays an important role in welding. Consumable electrode processes such as shielded metal arc welding (SMAW) and gas metal arc welding (GMAW) usually use direct current (DC), but the electrode can be charged either positively or negatively. In welding, the positively charged have a greater heat concentration and it affects the welding feature especially at the crack that is welded. If the electrode is positively charged, it will melt more quickly, increasing weld penetration and welding speed (Wikipedia: SMAW article, 2008). As the result, it helps the material from accepting too much heat and that can change the microstructure and prevent the material from defect. A negatively charged electrode will results in more shallow welds.

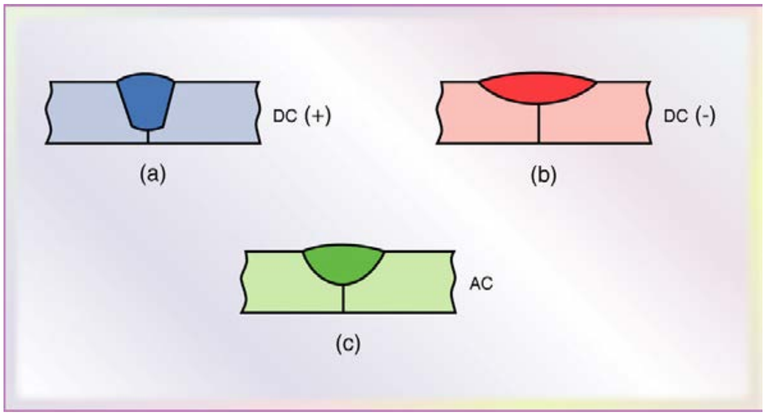


Figure 2.4: The effect of polarity and current type on weld beads: (a) dc current straight polarity; (b) dc current reverse polarity; (c) ac current.
(Taken from Serope Kalpakjian et al 2006)

2.2.4 Electrode

One of the most common types of arc welding is shielded metal arc welding (SMAW), which is also known as manual metal arc welding (MMA) (Serope Kalpakjian et al 2006). An electric current is used to strike an arc between the base material and a consumable electrode rod. The electrode rod is made of a material that is suitable with the base material being welded and is covered with a flux that protects the weld area from oxidation and contamination by producing carbon dioxide gas during the welding process. The electrode core acts as filler material, making separate filler unnecessary.

The process is very versatile, requiring little operator training and inexpensive equipment. However, weld times are rather slow, since the consumable electrodes must be frequently replaced and because slag, the residue from the flux, must be chipped away after welding or finishing. Furthermore, the process is generally limited to welding ferrous materials, though specialty electrodes have made possible the welding of cast iron, nickel, aluminium, copper and other metals (Wikipedia: SMAW article, 2008).

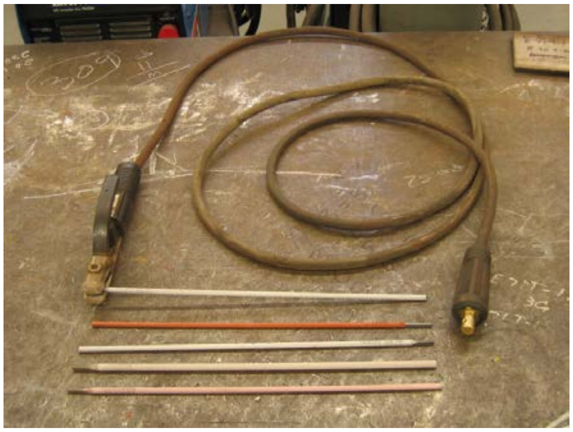


Figure 2.5: Arc welding electrode and holder

[Taken from Wikipedia: SMAW article, 2008]

2.3 PROPERTIES OF LOW CARBON STEEL

In carbon steel, they can be classified into three major categories that are low carbon steel also known as mild steel, medium carbon steel and high carbon steel. In this study, we are going to use only mild steel as the specimen to be weld and subjected with tensile test. Low carbon steel contain less than 0.30% of carbon compound(Serope Kalpakjian et al 2006).This type of carbon steel usually being used for common industrial component for example bolts, nuts, sheet, plate and tubes. The component that is made using this type of carbon steel usually does not required high strength (Serope Kalpakjian et al 2006).

2.3.1 Properties of AISI 1018

Below shows table for chemical composition and mechanical properties for AISI1018

Table 2.1: Chemical composition of AISI 1018
[Taken from Efunda 2008]:

Element	**Weight %**
Carbon , C	0.15 - 0.20
Manganese , Mn	0.60 - 0.90
Phosphorus , P	0.04 (max)
Sulphur , S	0.05 (max)

Table 2.2: Mechanical properties of AISI 1018
[Taken from Efunda 2008]:

Properties		**Temperature, T (^oC)**
Density (×1000 kg/m^3)	7.7-8.03	25
Poisson's Ratio	0.27-0.30	25
Elastic Modulus (GPa)	190-210	25

2.4 HEAT TREATMENT

Every element or type of steel, there are a certain improvement can be made. Usually improvement that is done is to improve the quality of the steel strength, hardness, brittleness or ductile properties. All of these parameters are used to assign whether the steel is good or bad to be used. In low carbon steel, heat treatment is the solution in order to improve the properties of the steel. There are much type of heat treatment that can be conducted for example tempering, annealing and quenching. This type of heat treatment will affect the microstructure and produce variety of mechanical properties (Serope Kalpakjian et al 2006).

2.4.1 Normalizing

In this study, normalizing is selected to be the type of treatment at the welded region. In this study, normalizing is selected because of the final product that going to produce is good than full annealing. Normalizing is the process of raising the temperature to over 60 º C (108 ºF), above line A_3 or line A_{CM} fully into the Austenite range. The temperature is used to fully convert the structure into austenite (Efunda, 2008), and then removed from the furnace and cooled at room temperature under natural convection. This results in a grain structure of fine pearlite with small and uniform grains structure (Serope Kalpakjian et al 2006) .

The resulting material is soft and the degree of softness depends on the actual ambient conditions of cooling. One of the research state that the slower cooling rate improve the mechanical properties (A.G. Olabi, M.S.J. Hashmi, 1996). Normalizing have slower cooling rate due to the ambient temperature that is used. Other than that, normalizing also results in higher strength and hardness and also lower ductility than heat treatment using full annealing (Serope Kalpakjian et al 2006).Other state also that normalizing can improve in toughness of a material (Geocities, 2008).

The main difference between full annealing and normalizing is that fully annealed parts are uniform in softness and machinablilty at all surface of the material since the entire part is exposed to the controlled furnace cooling. In the case of the normalized part, depending on the part geometry, the cooling is non-uniform resulting in non-uniform material properties across the part. This may not be desirable if further machining is desired, since it makes the machining job somewhat unpredictable (Efunda, 2008).

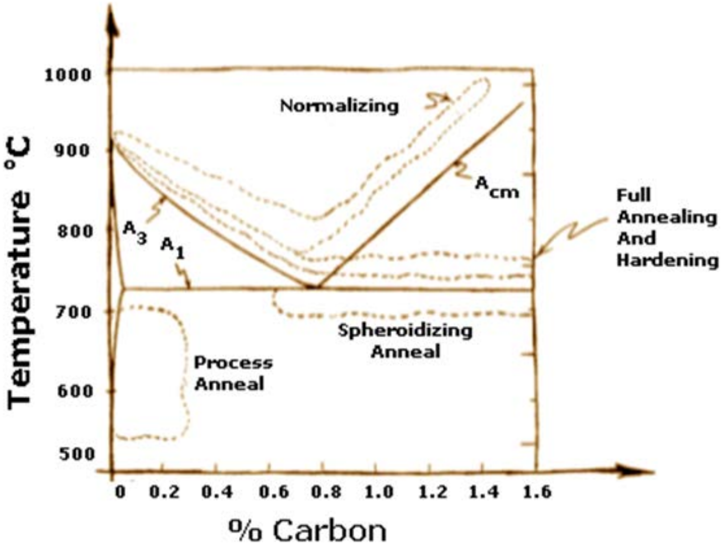


Figure 2.6: Heat Treatment graph

[Taken from Efunda, 2008]

2.4.2 Heat Affected Zone (HAZ)

Heat affected zone is a region where the microstructure of the region is differ than the microstructure of the base material because the region has been subjected temporarily to the elevated temperature during the welding process (Serope Kalpakjian et al 2006) .

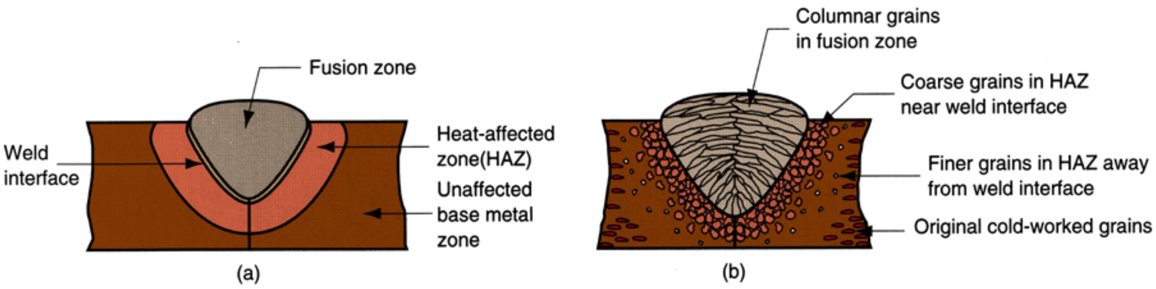


Figure 2.7: Heat Affected Zone

[Taken from Serope Kalpakjian et al 2006]

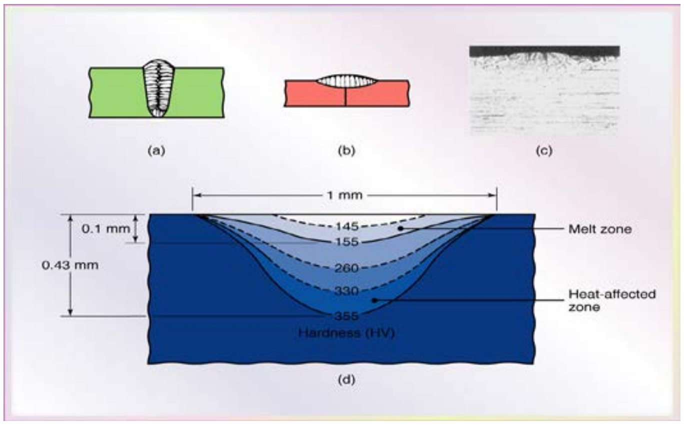


Figure 2.8: Grain structure in (a) deep weld and (b) shallow weld. (c) Weld bead on a cold-rolled nickel strip produced by a laser beam. (d) Microhardness (HV) profile across a weld bead

[Taken from Serope Kalpakjian et al 2006].

Heat affected zone is the weakest region that can initiate crack and propagate along the weld region and thus affect the strength, toughness, hardness and all mechanical properties at weld joint. When the base metal subjected to elevated temperature, the grains that are located at the heating region will grow in size and this region will be softer and have lower strength (Serope Kalpakjian et al 2006). In one of the research stated that the hardness value of the material decreased as the heat input increased (M. Eroglu, M. Aksoy 2000). Normalizing is the solution in improving the weld quality as well as the microstructure of the heat affected zone.

2.5 MICROSCOPE

Microscope is a machine that is used to observe structure that is too small and cannot be seen by naked eye. Most of the company that produce microscope insert standard magnification such as 100x , 200x , 50x , 20x , 10x and 5 x (Meiji microscope, 2008). But in order to observe a microstructure, a better microstructure is needed such as scanning Electron Microscope (SEM).

Figure 2.9: Microscope

Figure 2.10: Computer connected to the microscope

There are also some adjustments that can be made at the light control. Controlling the light that projected into the lenses helps users to identify the interested area. For a modern microscope, most of the microscope is connected to the computer for an easy observation unlike in previous era, microscope only can be observe and to capture the right picture of the structure is impossible unless the user draw by their self.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

In the welding fields, human specialty is still needed although there are many automatic machines were produce to help human and the machine serve better than human. Human could not resist from making any mistake and in welding also there are many defect can occur when welding in the process. In order to study the behavior of the crack at the weld area, the crack was simulated in the welding process.

3.2 MATERIAL CUTTING

In machining process, mild steel was cut into 20 mm x 70 mm using shear machine. From the raw material, 22 pieces of sheet metal was produce after the cutting was done at the shear machine. Most of the pieces was in the corrosion and need to be removed the corrosion using sand paper before undergoes welding process. At the end, there were 11 pairs of sheet metal that were welded.

Flow of methodology process

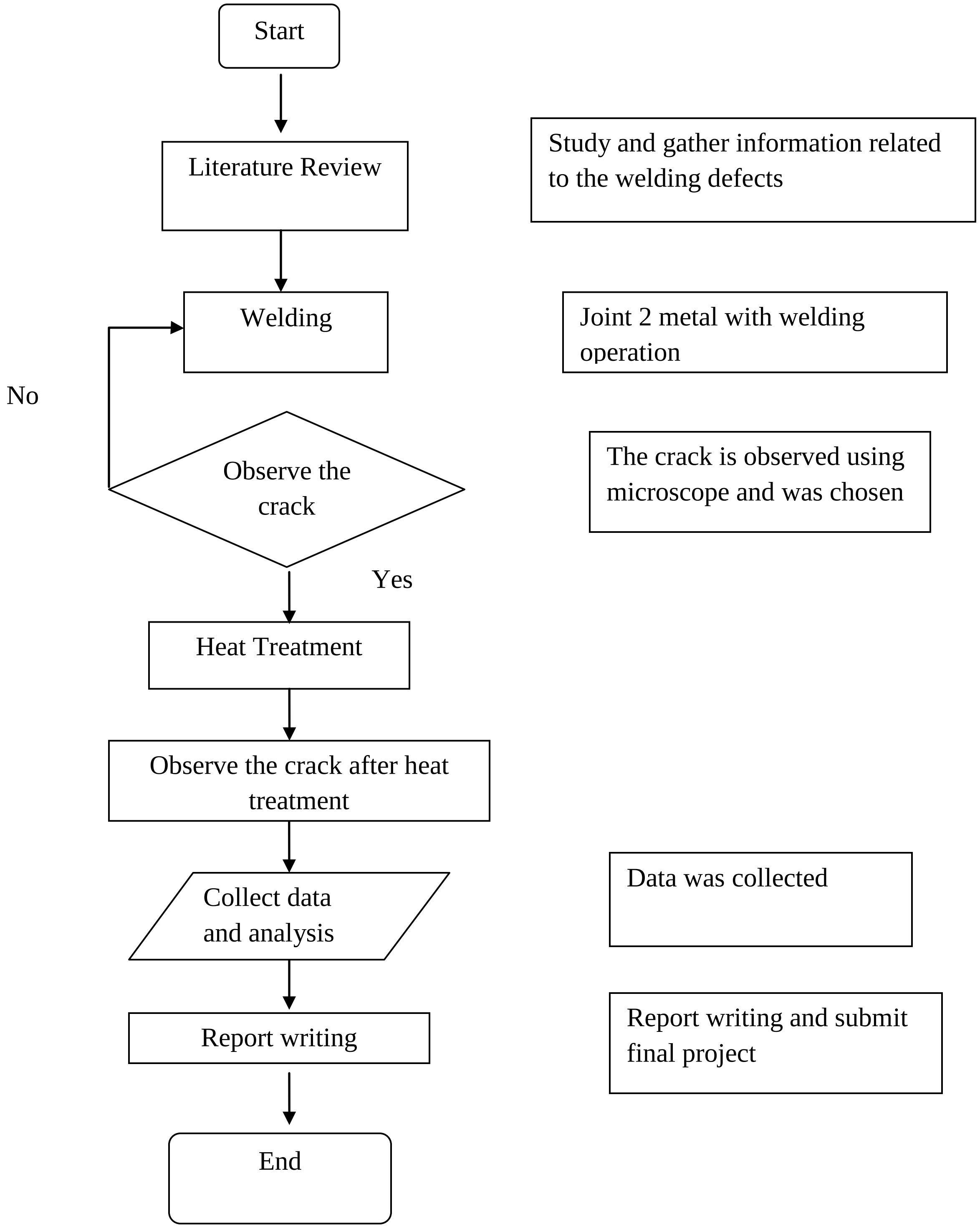


Figure 3.1: Flow Chart of overall progress

3.3 WELDING PROCESS

After all the sheet metal was polished by sand paper, welding takes part in the joining between two sheet metal. In the welding process, proper voltage and current selection important because it affect the fusion region and the sheet metal as well. Types of joint design also determine the difficulty and the successfulness of welding process.

3.3.1 Butt Weld Joint Design

In joint design, there are many type of joint design that can be applied in welding process. There are some guidelines that can be used in process selection of certain joint design and this process involve in some consideration. For example:

a) Configuration of the parts or structure to be joined, joint design, thickness and size of the components and number of joints required.
b) The method used in manufacturing the components to be joined.
c) Type of materials involved, which may be metallic or non metallic
d) Location and accessibility
e) Application and service requirement such as type of loading, stress generated and the environment.
f) Effect of distortion
g) Cost involved in the edge preparation, joining and postprocessing
h) Costs of equipment, material, labor and skills required and the joining operation.

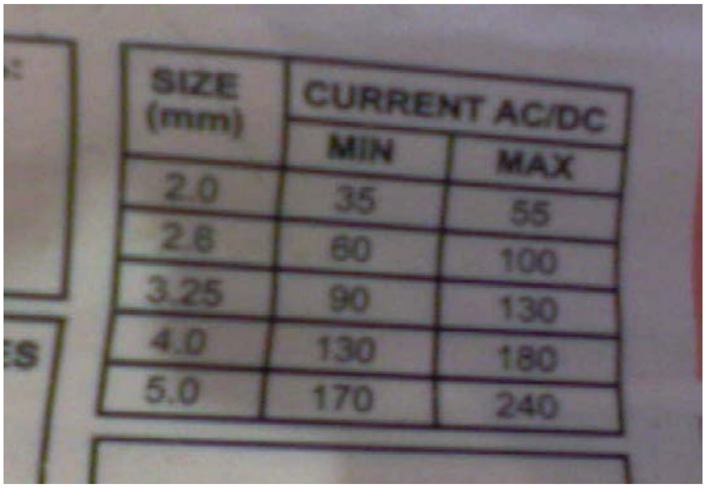
After considering all of the consideration that affects the decision of joint design, the butt well was selected as the main joint design. This design was selected because of some reasons:

a) There is no need in application and service requirement because this study is not for the purpose of service or applying in the industry.
b) The cost for preparation is low and reliable to the study.
c) There limited number of joint in this study.
d) No loading or testing going to be applied in this welding structure.

3.3.2 Current and Voltage Selection

In welding, current is one of important variable that determine the degree of heat that will be transfer and heat the microstructure of the workpiece. Consideration on this variable is extremely important although there already a specification that was stated by manufacture at the electrode package. In this study, alternating current power supply is used and the voltage is fixed. Voltage that was used is 230 V to avoid the workpiece from receiving too many heat and damaging the workpiece.

In the selection of current, the diameter of the electrode is the main guide in selecting the proper current. As stated in the manufacturer package, the current that is allowed in the range of 60 to 100 ampere. Although there is stated also the current selection on the power supply with different range, the range still can be apply by electrode in the welding process. After all the parameter was set up, the welding was done as the propose to simulate the crack and the perfect welding bead is not necessary in simulating the crack.



SIZE (mm)	CURRENT AC/DC	
	MIN	MAX
2.0	35	55
2.6	60	100
3.25	90	130
4.0	130	180
5.0	170	240

Figure 3.2: Current range selection from manufacturer

Figure 3.3: Current range selection between 60 to 100 from power supply

3.4 POLISHING THE WELD REGION

After welding is done, the slag that covered the weld bead need to be remove so that the crack on the weld bead can be observe by microscope. Smashing the slag by using hammer can smash the slang into pieces and revealing the weld bead to be polished by sand paper. The smaller the sand grain at the sand paper the better the surface can be observe by microscope. Using some lubricant that is used in polishing also help in revealing the surface of the crack. In this study, the weld bead not going to be grind in order to maintain the original structure and the simulated crack.

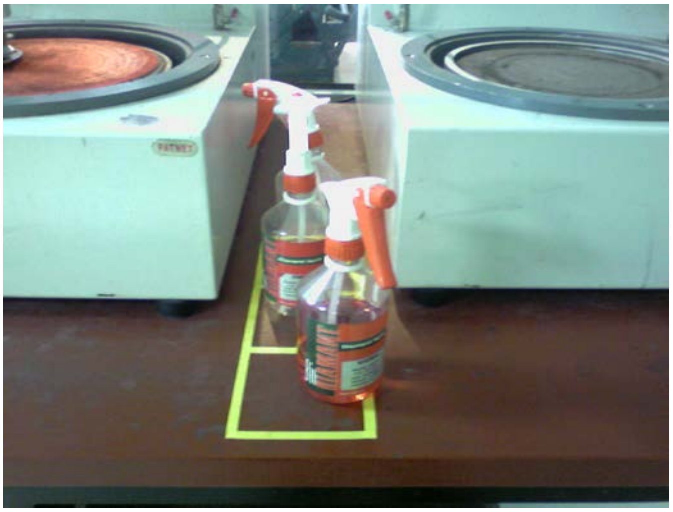


Figure 3.4: Aerosol diamond polishing lubricant

Polishing also necessary after the heat treatment was done. Sand paper and polishing lubricant is needed to removing the surface that was burn during the heat treatment. This process is repeatable until the crack that was observed on the microscope is revealed as before the heat treatment to ensure the data that was collected is correct and the error is reduced.

3.5 OBSERVATION UNDER MICROSCOPE

Observation is a action on searching, scanning and skimming feature or object. In the microscope, observation using different type of magnification is necessary to verify the data that was collected is correct. In this study, micro-crack is the interested features and it cannot be observed using naked eye even using the undistructive method.

Figure below shows the process flow in observation the crack at the workpiece:

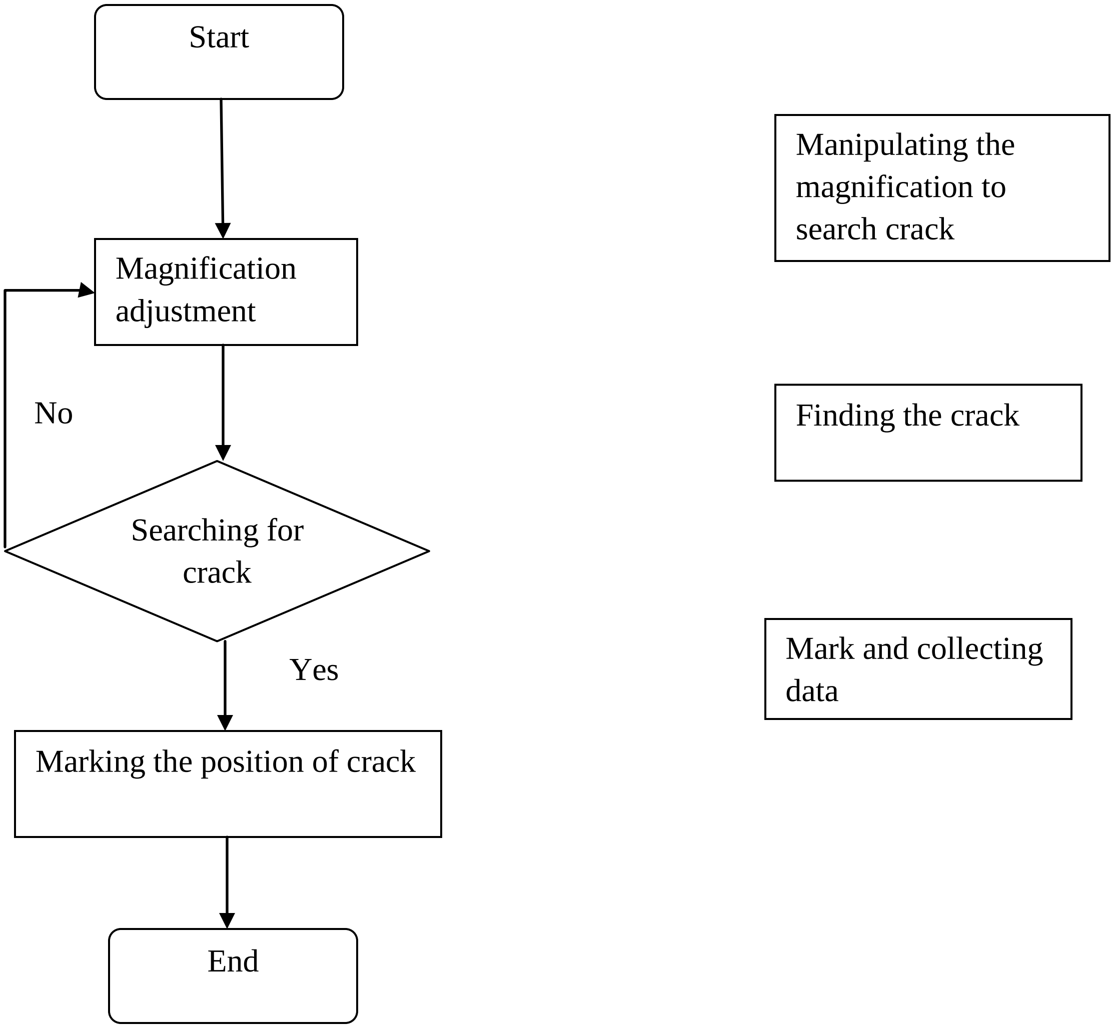
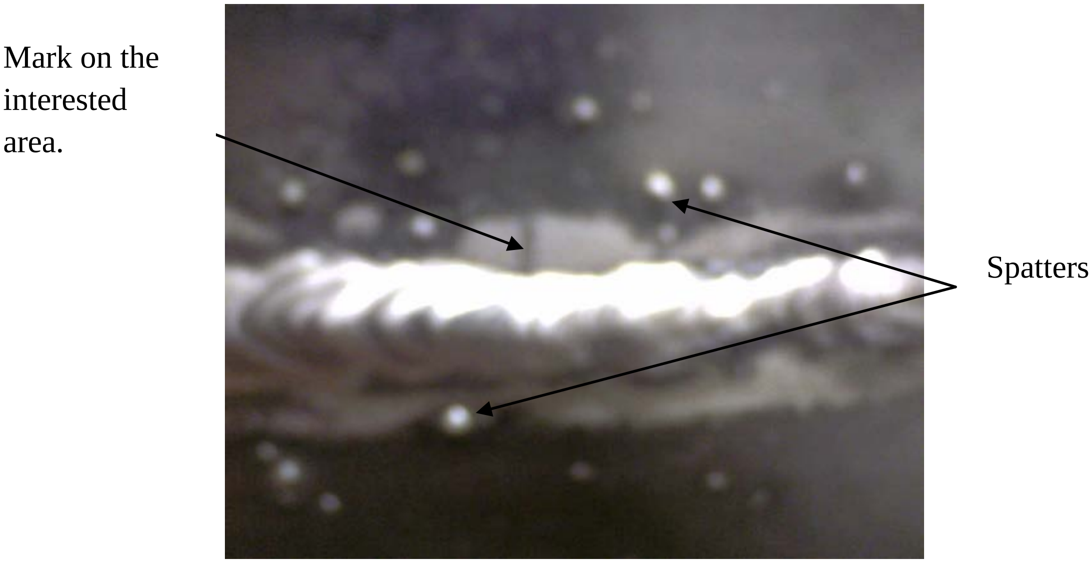


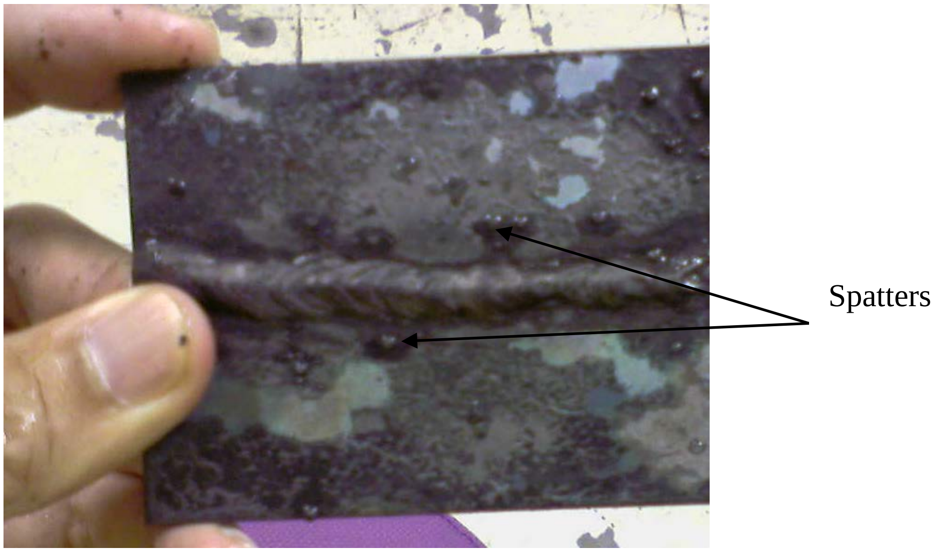
Figure 3.5: Flow progress of the microscope



Mark on the interested area.

Spatters

Figure 3.6: Mark position on the workpiece before heat treatment.



Spatters

Figure 3.7: The mark after heat treatment

Observation using microscope also done after the heat treatment was done. Although the marking was banish because the surface was burned in the oven, but the spatter on the workpiece also as a marking system to indicate the position of the previous crack. After polishing the burned area around the crack, the workpiece will be observed again to collect the data about the behaviors of the crack after the heat treatment was done.

3.6 HEAT TREATMENT

Heat treatment is a process for improving the structure of the workpiece. Annealing is done to the workpiece and the cooling process was normalizing. In the annealing process, the workpiece was inserted into the oven and parameter was set. The burning chamber must be in ambient temperature to set as a fix variable. The parameter that was set at the information needed on the oven stated below:

Time, T_1 = 01:00 hours
Time, T_2 = 01:00 hours
Temperature, C max = 700 ^{o}C
Time Waiting, T_0 = 00:00 hours

After all the parameter was setup, the oven is closed to burn the workpiece according to the data inserted. T_1 is the time for the heating rate. The workpiece is going to burn from ambient temperature up to 700^{0}C in one hour.T_2 is the time for the workpiece was leave to be heated for a period. In this study, the workpiece was leaved for one hour. T_2 also known as soaking time. Time for the structure of the workpiece changing after receiving the heat.

After the soaking was done, the burned workpiece was taken out from the workpiece to be cooled using ambient air. This process of cooling known as normalizing. Normalizing take few minutes or even hours to cool down the material until the material temperature as same as ambient temperature. After the normalizing was done, the polishing technique was done to removing the burned pieces on the workpiece to reveal the interested region for a purpose of observation on the microscope.

Figure 3.8: The workpiece after the heat treatment is done.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 INTRODUCTION

This chapter will discuss about problem and consideration on fabricating and analyzing the result that was obtain after the microscope was used and all necessary information that was needed. The result will be analyzed is base on the data that was collected. The data will be sorted into a table for an easy information display.

4.2 CRACK ANALYSIS

There are many types of cracks that can be found in welding region. Crack can be classified as hot crack and cold crack. Hot crack is types of crack that can be occur while the joint is still at the elevated temperatures while the cold cracks develop after the weld metal was solidified (Serope Kalpakjian et al 2006). According James F.Lincoln, in a welding region, the least crack encounter is transverse crack. There are various type of crack for example transverse crack, longitudinal crack, underbead crack and toe crack but in this study the only crack that interested is longitudinal crack that is located near heat affected zone.

The picture below shows the crack that is located near to the heat affected zone but still in the weld bead. Longitudinal crack occur at this region because heat affected zone is the weakest region in welding structure. The weakest point will usually initiate a problem. Longitudinal crack situated parallel to the weld bead. The crack was measured using software known as image analyzer that connected to the microscope.

4.2.1 Crack before heat treatment

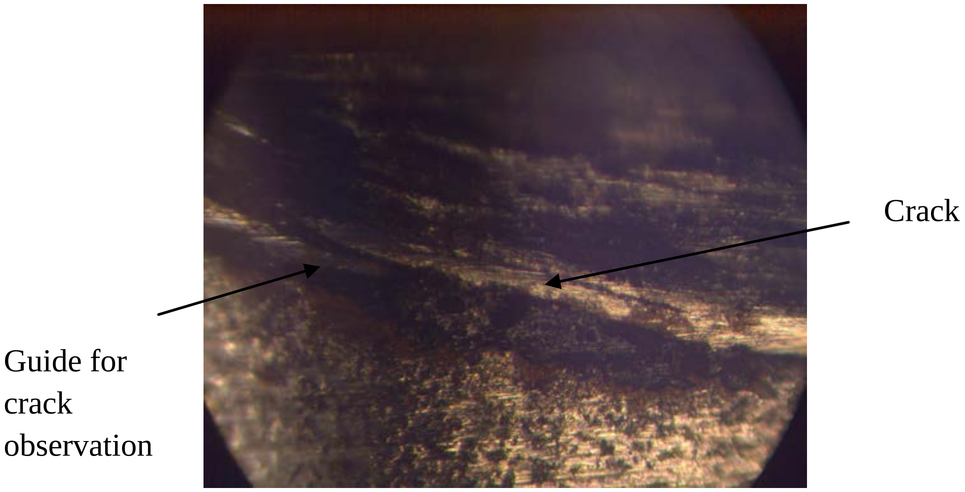


Figure 4.1: Longitudinal crack at 10x magnification

Above figure show longitudinal crack that located almost at the heat affected zone for 10x magnification. The crack cannot be observed clearly in this magnification and it affects the result. To reduce the error that might get, higher magnification is used to observe and measured the length of the crack before the heat treatment. 20x and 50x was used in order to get an accurate result.

Using 100x and 200x magnification is not applicable because the crack cannot be observed instead of observing crack but the structure of the sheet metal is the result of the observation. Some guide for crack observation was selected to eliminate uncertainties in selecting and measuring the crack after the heat treatment. This done to ensure that the right cracks that were observe before the heat treatment is the same crack after the heat treatment. The guide located near the crack region and it can be observe only by using microscope.

4.2.2 Crack after heat treatment

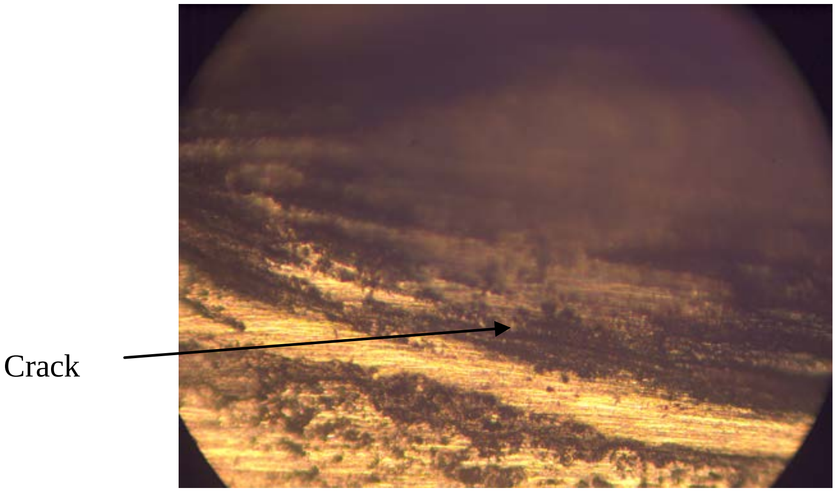


Figure 4.2: Crack after the heat treatment using 20 x magnifications

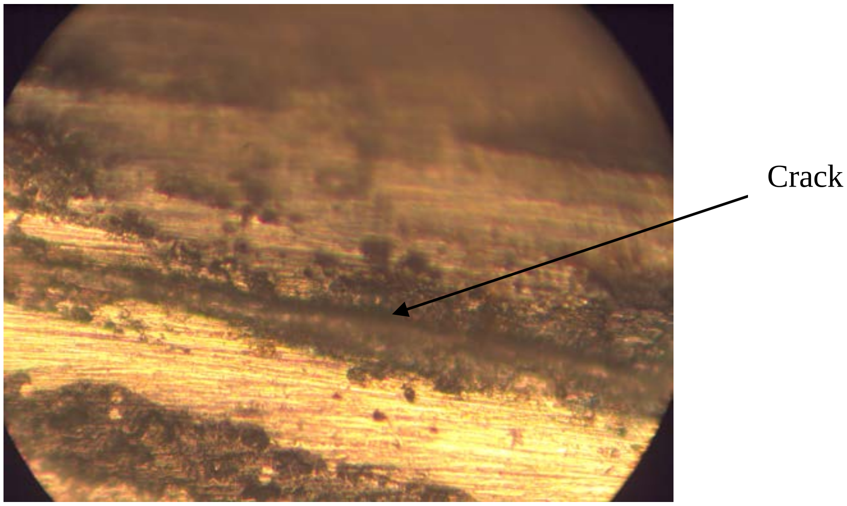


Figure 4.3: Crack after heat treatment using 50 x magnifications

From above photos, shows the crack after the heat treatment using 20x and 50x magnifications. Both of the crack is the same crack but in different magnification. After analyzing the photos, the crack shows some improvement in shortening the length of the crack. Although there was a study that stated that crack cannot be eliminated by using heat treatment and can only be eliminated using physical treatment, but micro-crack in this study shows some improvement. Analyses prove that the crack cannot be eliminated and the propagation of the crack cannot be stop but the propagation of the crack can be slowed by heat treatment. The crack shortened approximately 40 % in this diagram.

4.3 DATA INTERPRETATION

Data from all the observation was collected and arranged into a table for analysis to be done. A comparison was made between before and after the heat treatment and the percentage was calculated using simple mathematic equation.

Table 4.1: Data collected from three specimens

No of experiment	**Length of crack**		**Percentage (%)**
	Before heat treatment (µm)	**After heat treatment (µm)**	
1	1212	784	35.5
2	1358	774	43.1
3	1295	704	45.6
			Average = 41.4

Based on the data above, for the first workpiece the crack that was observe before the heat treatment was 1212 µm and after heat treatment the length was reduce to 784 µm and the percentage difference was 35.5% and that carry amount of 428 in depletion of length. The second experiment at the initial crack was 1358 µm and the final length was 774 µm. The change in length was 584 µm and it carries an amount of percentage for 43.1%. The third experiment shows that 1295 µm total length of the crack and the final length after the heat treatment were 704 µm. The amount that decreased by heat treatment was 591 µm and in percentage it was 45.6%. Comparison between the first and the second shows the different in 7.6%.

An average value is taken to reduce the error that get. From the different can be concluded that the length for the third experiment was reduces more effectively than the first and the second experiment. The difference influenced by the ambient temperature. For the first experiment, after the heating was done, the specimen was taken out directly from the furnace and the ambient temperature affected the cooling rate thus it affects the crack elongation.

4.4 DISCUSSION

For both of the second the third experiment, the length that was produce was approximately the same. Both of the experiment was done in the same day and the same method. The effect of ambient temperature is the uncontrollable because normalizing using ambient temperature. Ambient temperature work as a critical part that affect the type of crack produce and the features of crack after the heat treatment. From the experiment also show that the effectiveness in using the cooling process that is normalizing is mainly depends on the ambient temperature. The calculation for the difference in percentage for the crack can be calculated as below:

$$percentage\ difference = \frac{length\ before\ heat\ treatment - length\ after\ heat\ treatment}{length\ before\ heat\ treatment} \times 100\%$$

= (1212-784)/784 x 100

= 35.5% difference.

In one of the journal (Kaiping Peng et al 2007), state that grain refinement can improve in crack growth by using annealing and groove pressing. In the research, the higher the temperature for annealing produces higher fracture with groove pressing. Shows that heat treatment contribute in reducing the crack growth. Although there were no research about the effectiveness of the heat treatment toward preventing the crack growth, but heat treatment still reliable n order to reduce the crack growth. Application of some physical pressure also can be applied in order to prevent crack growth.

Most of the references state the quenching media is good in preventing crack growth especially in development of supersaturation. Slow quenching is applied as stated in the (Key to Metal, 2008).In other reference (Aviation, 2008), state also that heat treatment can avoid from crack by applying correct heat capacity, viscosity, and temperature of quenching media, that will produce successful hardening of steel Although the quenching heat treatment is used but the result that is crack can be avoided is still reliable in this study.

Other than ambient temperature, the annealing temperature also can be taking as consideration. In (A.G. Olabi and M.S.J. Hashmi, 1996) state that, the maximum improvement of the mechanical properties can be obtained at 650^{o}C for AISI 1020 and the longer the soaking time the batter the mechanical properties produce. By rehearsing the conclusion form above statement, this study can be done in order to improve the mechanical properties thus improvement in mechanical properties relatively related to the improvement in structure.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

As a conclusion, the objective for this project is achieved. The heat treatment can reduce the crack from propagate but in only available for micro-crack. But heat treatment cannot eliminate the crack that was produce unless there was a physical treatment is done on the crack for examples by welding the weld region again. In micro-crack, the heat treatment process using annealing followed by normalizing give small effect on reducing the micro-.Although micro-crack is not to be concern in most of the journal, micro-crack helps in propagation of major crack and bring up problem in the welding structure.

5.2 RECOMMENDATION

There are several steps and procedures that could have been taken to improve the result thus, obtaining more accurate and reliable data the steps that can be taken is stated below:

a) Using a controllable ambient temperature will help on getting accurate data.
b) The study about the crack microstructure also can be done as a relationship in crack behavior.

c) Using Scanning Electron Microscope can get the most accurate result and revealing the true microstructure of the weld region.

In the future this study can be done by using other types of heat treatment. For example using full annealing . Using difference variable such as different soaking time, different heat rate, and different material. Quenching also can be used as one of the heat treatment in improving this study. As stated in reference (Key to Metal, 2008) and (Aviation, 2008), both of the reference used quenching as the heat treatment in preventing the crack. For a welding purpose, an automatic welding can be used to identify the crack other than simulating the crack.

REFERENCES:

Emin Bayraktar a, Dominique Kaplan, Christophe Buirette, Marc Grumbachb, *Application of impact tensile testing to welded thin sheet, Journal of Materials Processing Technology 145 (2004)*

Serope Kalpakjian,Steven Schmid,*Manufacturing Engineering and Technology fifth edition*,(2006)

Wikipeida : Arc Welding, 2008,
http://en.wikipedia.org/wiki/Arc_welding, 15/02/08 10.13PM

A.G. Olabi and M.S.J. Hashmi, *The Microstructure and Mechanical Properties of Low Carbon Steel Welded Component After The Application of PWTHs, Journal of Materials Processing Technology 56 (1996) 88-97*

L.X. Chen, P. Bhandhubanyong, W.Vajraguptra, C. Somsiri, *Plastic Properties of Low-Carbon Steel Sheets, Journal of Materials Processing Technology 63 (1997) 95-99*

R.G. Thiessen, I.M. Richardson, J. Sietsma, *Physically based modelling of phase transformations during welding of low-carbon steel, Materials Science and Engineering A 427 (2006) 223–231*

A. Gu ral , B. Bostan, A.T. O zdemir, *Heat treatment in two phase region and its effect on microstructure and mechanical strength after welding of a low carbon steel, Materials and Design 28 (2007) 897–903*

M. Eroglu, M. Aksoy, *Effect of initial grain size on microstructure and toughness of intercritical heat-affected zone of a low carbon steel, Materials Science and Engineering A286 (2000) 289–297*

Efunda, 2008,
http://www.efunda.com/processes/heat_treat/softening/annealing.cfm , 10/03/2008, 2.11AM

Wikipedia, 2008,
http://en.wikipedia.org/wiki/Annealing_%28metallurgy%29, 14/3/2008, 9.20PM

Geocities, 2008
http://www.geocities.com/haimanaua/htdocs/steels/1018.html 14/3/2008,9.24PM

Science Learning Network Home, 2008,
http://www.mos.org/sln/SEM/ 14/3/2008, 9.20PM

Wikipedia, 2008,
http://en.wikipedia.org/wiki/Scanning_electron_microscope , 11/2/2008, 11.15PM

Wikipedia: SMAW article, 2008,
http://en.wikipedia.org/wiki/Shielded_metal_arc_welding 11/2/2008, 11.20PM

Esab, 2008,
http://www.esabna.com/us/en/education/knowledge/weldinginspection/Weld-Discontinuities-Part-3.cfm/11/2/2008,11.25PM

The James F. Lincoln, 2008,
http://content.lincolnelectric.com/pdfs/knowledge/articles/content/weldcracking.pdf , 15/10/2008,8.45PM

Kaiping Peng, Lifeng Su, Leon L. Shawb, and K.-W. Qiana, *Grain refinement and crack prevention in constrained groove pressing of two-phase Cu–Zn alloys, Scripta Materialia 56 (2007) 987–990*

Key to Metal, 2008,
http://www.key-to-metals.com/Article39.htm , 30/10/2008, 11.30PM

Aviation, 2008,
http://www.tpub.com/air/15-30.htm , 30/10/2008,12.00PM

The James F. Lincoln, 2008,
http://www.efunda.com/materials/alloys/carbon_steels/show_carbon.cfm?ID=AISI_1018&prop=All&Page_Title=Low-Carbon%20Steels 21/10/2008,1.45AM

Meiji microscope, 2008,
http://www.meijitechno.com/invertedmetallograph.htm , 21/10/2008,2.15AM

Appendix A

Properties of the electrode

EMICAL COMPOSITION %:

bon	0.07
ganese	0.45
on	0.35
hur	0.010
phorus	0.010

ELD METAL PROPERTIES

rength	440 N/mm^2
Strength	490 N/mm^2
on	23%
n of Area	62%
trength	68J @ 0°C

SIZE (mm)	CURRENT AC/DC	
	MIN	MAX
2.0	35	55
2.6	60	100
3.25	90	130
4.0	130	180
5.0	170	240

BERAT/WEIGHT 5KG

MO
NO
TE
TC

Appendix B

Welding information on power supply

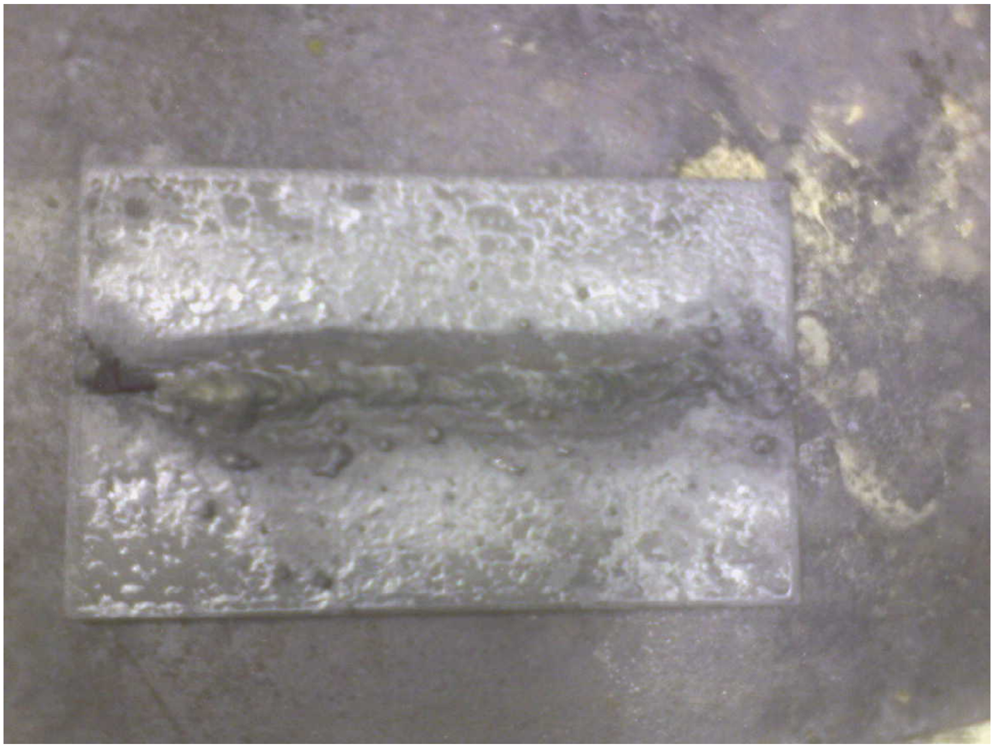
	1~ — 1~			EN 50060 EN 50199		
	U_0 46 ÷ [illegible]V	50/60Hz		I_2 50 - 130A		
	⌀mm	1.6	2	2.5	3.25	4
	I_2 A	50	60	80	115	—
	nc	28	18	9	6	—
	nh	6	5	3	2	—
	U_1 230 V		T 28 A		I_1 MAX 28A	
1~ 50/60Hz	U_1 400 V		T 16A		I_1 MAX 16A	
			IP 21		H	

Appendix C

Others polishing lubricant

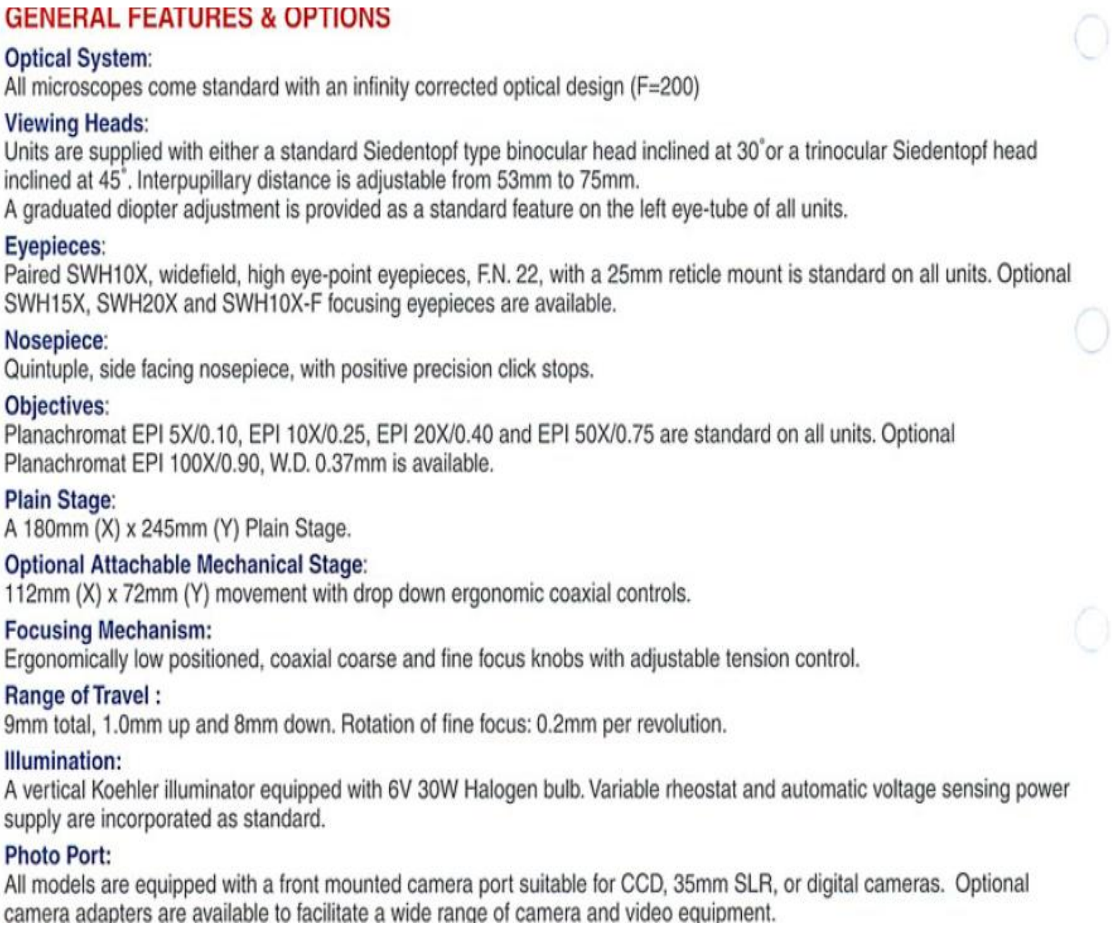
Appendix D

Actual product after heat treatment



Appendix E

General features of the microscope IM7000



GENERAL FEATURES & OPTIONS

Optical System:
All microscopes come standard with an infinity corrected optical design (F=200)

Viewing Heads:
Units are supplied with either a standard Siedentopf type binocular head inclined at 30°or a trinocular Siedentopf head inclined at 45°. Interpupillary distance is adjustable from 53mm to 75mm.
A graduated diopter adjustment is provided as a standard feature on the left eye-tube of all units.

Eyepieces:
Paired SWH10X, widefield, high eye-point eyepieces, F.N. 22, with a 25mm reticle mount is standard on all units. Optional SWH15X, SWH20X and SWH10X-F focusing eyepieces are available.

Nosepiece:
Quintuple, side facing nosepiece, with positive precision click stops.

Objectives:
Planachromat EPI 5X/0.10, EPI 10X/0.25, EPI 20X/0.40 and EPI 50X/0.75 are standard on all units. Optional Planachromat EPI 100X/0.90, W.D. 0.37mm is available.

Plain Stage:
A 180mm (X) x 245mm (Y) Plain Stage.

Optional Attachable Mechanical Stage:
112mm (X) x 72mm (Y) movement with drop down ergonomic coaxial controls.

Focusing Mechanism:
Ergonomically low positioned, coaxial coarse and fine focus knobs with adjustable tension control.

Range of Travel :
9mm total, 1.0mm up and 8mm down. Rotation of fine focus: 0.2mm per revolution.

Illumination:
A vertical Koehler illuminator equipped with 6V 30W Halogen bulb. Variable rheostat and automatic voltage sensing power supply are incorporated as standard.

Photo Port:
All models are equipped with a front mounted camera port suitable for CCD, 35mm SLR, or digital cameras. Optional camera adapters are available to facilitate a wide range of camera and video equipment.