THE EFFECT OF POST WELD HEAT TREATMENT (PWHT) TEMPERATURE ON AUSTENITIC STAINLESS STEEL 316L WITH GAS METAL ARC WELDING (GMAW)/METAL INERT GAS (MIG)

by

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CERTIFICATION

CERTIFICATION OF APPROVAL

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Approved by,

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TRONOH, PERAK

May 2014

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified references and acknowledgements and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

AZIAH AULUWON BINTI FAUTHAN

ABSTRACT

The effect of post-weld heat treatment temperature on 316L stainless steel using metal inert gas (MIG) as welding method is studied. During welding processes, the temperature of molten weld pool is high meanwhile the rest of steel is almost at ambient temperature. This will lead to the changes the microstructure of steel and resulting in property changes that make steel weaker and brittle. Post Weld Heat Treatment (PWHT) able to eliminate these effects by heating the weld area in a controlled manner using optimum temperature. The present work involves the dissimilarities of microstructure and physical properties on welded steel. Steel plates of 5mm thickness were welded by MIG process. After welding processes, the steel plates will be cut into four pieces according to the standard of testing that been decided for each plate; microstructure test, hardness test and tensile test. For tensile testing, the specimens were cut into four dogbone shape according to ASTM E8. This study uses common standards to make sure all results are valid. Heat treatment consisted annealing at 300^{o}C, 600^{o}C and 900^{o}C for half an hour and cooled by ambient air. One specimen is left without heat treatment to see the difference between before and after heat treatment. For microstructure testing, scanning electron microscope (SEM) was used. The relevant microstructural test was done in the interpretation of changes before and after welding structure. The hardness values are rising with the increasing of annealing temperature. However, when a hardness test was done on 900^{o}C heat treatment specimen, it shows decreasing. This is due to $M_{23}C_6$ carbides form rapidly in this temperature and can lead to embrittlement and loss of toughness. The grain size increases to a certain size and the work piece is hardened through this post weld heat treatment. This study involved the present results comparing to the values reported in literature to obtain the best result.

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CHAPTER 1: INTRODUCTION

1.1 BACKGROUND OF STUDY

Austenitic stainless steel is the candidates of high standard demand under stringent operating conditions. It is precisely, corrosion-resisting steels which having excellent resistance to corrosion. Stainless steels can be welded using several different procedures such as shielded metal arc welding (SMAW), gas tungsten arc welding (GTAW) and gas metal arc welding (GMAW) [11]. In this study, GMAW will be used as main welding methods to weld 316L stainless steel thin plate. This method allowed all position welding on thin materials [6]. GMAW uses shielding gas; oxygen, argon and nitrogen to protect weld pool. In order to modify microstructure after welding process, the specimen will undergo post weld heat treatment (PWHT) after weld two joints of plate together. Detailed of investigation on microstructure and mechanical properties will be find out after PWHT in order to analyze metal hardness, heat affective zone (HAZ) and other properties by doing some testing on the specimen.

Many of stainless steels have good low temperature toughness and ductility [11]. Most of them exhibit good strength properties and resistance to scale at high temperatures. The ability of welding a stainless steel is depending on their chemical composition. Austenitic chromium-nickel falls under 300 series. It is one of alloy type that is clearly different from others categories of steel. It is the most widely used type of stainless steel. It contained at least 7% of nickel which improves the corrosion resistance of chrome steels, a raised ductility, non-magnetic properties, significant work hardenability include for low temperature and has good weld ability [9]. Carbon is added to improve strength at high temperature and nitrogen also act to improve strength of metal. Austenitic stainless steels are used in house wares, containers, industrial piping and vessels and constructional structures.

There are many welding methods can be used to joints two materials together. We will discuss more on process of MIG or GMAW. As other welding processes, GMAW or MIG welding is used to protect the welding area from atmospheric gases such nitrogen and oxygen. Both of gases may cause fusion defects, porosity, and weld metal embitterment if they come in contact with the electrode, the arc, or the welding metal [9]. The joints will be obtained by GMAW process in which melts metal by heat supplying an electric arc established between a continuously fed filler wire electrode [2]. In addition, it has high quality of weld and can be produced faster.

In general, preheat and interpass temperature is not required for this type of stainless steel. High preheat and interpass temperatures will slow the cooling rate and will result carbide precipitation damage. However, post heat weld treatment (PWHT) may be used to reduce residual stresses after welding completed. The coefficient of thermal expansion is much larger for austenitic stainless steels than for ferritic stainless steel [15]. Postweld stress relief may be necessary to reduce distortion in component, particularly if it is required to maintain dimensional stability. The heat treatment temperature that is selected should be dependent on the intention of thermal treatment (stress relief or microstructure modification) [15]. The aim for this investigation is to analyze the effect on weld and base metal using different temperature of heat treatment.

In conclusion, joining two joint of materials together will be more effective in some ways; type of welding process, type of materials and temperature heat treatment. It is necessary to decide welding procedure specification (WPS) before start the welding process according to the standards. This research will be more focusing on the effect of different microstructure and mechanical properties after heat treatment.

1.2 PROBLEM STATEMENT

Post-weld heat treatment may be required during production welding and is most generally used for stress relief with the overall aim of removing internal or residual stresses that may have been generated during welding. It is generally aids in the removal of or reduction of the risk of brittle fracture after welding as well as stress corrosion, among other metallurgical problems associated with welding at high temperatures. These thermal treatments therefore assist in assuring weld quality, performance and integrity. However, heat treatment temperature selected should be dependent based on type of metal, intention of thermal treatment. The wrong combination of temperature can cause embrittlement and loss of toughness.

1.3 OBJECTIVES AND SCOPE OF STUDY

- To investigate the effect of different temperature PWHT on microstructure properties of base metal.
- To investigate the effect of different temperature PWHT on mechanical properties of base metal.

The study consists of choosing the right type of steel to be joined together. The material used for this study is stainless steel 316L which has low carbon compared to other stainless steel. MIG process is used to weld the joint of base metal together because it is a faster welding process. Different temperature of PWHT is tested on specimen using no heat treatment, 300^{o}C, 600^{o}C and 900^{o}C. There are three testing that will be conducted during this study which hardness test, microstructure tests and tensile strength test. From the testing, we can see the difference of metal with and without heat treatment. All testing will be conducted using suitable standards which ASTM E18 and E8M. This standards will make sure, all experimental works been tested using correct procedure and valid.

CHAPTER 2: LITERATURE REVIEW/ THEORY

2.1 AUSTENITIC STAINLESS STEEL 316L

Stainless Steel 316L or austenitic chromium nickel is austenitic stainless steel enhanced with 2.5% Molybdenum in order to provide high corrosion resistance. Molybdenum also added to improve the creep resistance of the steel at elevated temperatures. Besides Molybdenum, Chromium also provides the basic corrosion resistance to stainless steels [12]. It is proved that it will increase corrosion resistance and also has resistant to sulphates and other salts. Mechanical properties for this base metal generally; yield strength is 30 ksi, tensile is 75 ksi and elongation for this base metal is 40%. In addition 316L has low carbon which about 0.03% of carbon only. Lower percentage of carbon will eliminate the risk of dropping corrosion resistance when exposed to some temperature for a long period. Austenitic steels have about 50% higher thermal expansion compared to ferritic and duplex steel and the melting point of austenitic stainless steel is slightly lower than melting point of mild-carbon steel. Because of lower melting temperature and lower thermal conductivity, welding current is usually lower. However, it offers the user relatively high strength to a moderate cost [11]. Other criteria need to be taken care is also welding filler metals which the selection of it is based on the composition of the stainless steel. Filler metal alloy for welding the various stainless steel base metals are : Cr-Ni-Mn (AISI No. 308); Cr-Ni-Austenitic (AISI No. 309, 310, 316, 317, 347);Cr-Martensitic (AISI No. 410, 430); Cr-Ferritic (AISI No. 410, 430, 309, 502) [12]. Since this research using Austenitic Stainless Steel, this experiment will use AISI No.316 as filler metal. But it is possible to weld stainless steel base metal using stainless steel filler metal which has different group.

2.2 GAS METAL ARC WELDING/ METAL INERT GAS

Welding is done by melting the work pieces and adding filler material to form a pool of molten material that cools to become a strong joint [9]. There are some processes can be done for welding such Tungsten Inert Gas (TIG), Shielded Metal Arc Welding (SWAW), Gas Metal Arc Welding (GMAW) and others. Gas Metal Arc Welding process is widely used for thicker materials since it is a faster welding process [12]. GMAW used the same gas shielded arc as gas tungsten arc but replacing the tungsten electrode with a continuously fed electrode wire [6]. It is a common welding process used in conditions where air current will not harm the external shielding gas; used to protect weld pool. Flat position welding requires the use of argon shielding with 2% or 5% oxygen or special mixtures. The oxygen helps producing better wetting action on the edges of the weld [12]. There are variety electrode wires; steel, stainless steel, aluminium, composites and silicon bronze. Since this research used stainless steel base metal, the electrode wire also must be used from stainless steel to make sure joining of materials is strong. We used GMAW because this process has many advantages such as it produced little slag so it require minimal post weld cleaning, it produce high quality weld and easy to handle whereas anyone can weld after a very short amount practice. Besides, one electrode can be used on various thicknesses of materials productively compared to other processes.

2.3 POST WELD HEAT TREATMENT (PWHT)

Post Weld Heat Treatment (PWHT) is a treatment after welding to improve the properties of weldment. The need of heat treatment is often driven by code or application requirements [12]. The goal for PWHT is to increase the resistance of brittle fracture and relaxing residual stresses. Before heat treatment, chemical composition of the base metal must be acknowledged to ensure optimum temperature for PWHT is chosen. Depending on the heat treatment, the microstructure of stainless steel can be different [4]. Properties of deposited weld can be different after relieving. According to the research that been made, this example shows the differences before and after PWHT on 316L which may has 75ksi tensile strength in “as welded” condition. However, after stress relieving, it may have tensile strength of only 65ksi. This shows heat treatment can change mechanical properties of base metal.

2.4 EFFECT OF PWHT TEMPERATURE

From research that has been made, there will be effect on base metal based on different temperature during PWHT. This will result the base metal and joint become stronger as its yield strength will increase. However, the wrong combination of temperature, time, and cooling rates can cause precipitation of detrimental phases, such as carbides, nitrides and sigma-phase [12]. It is not necessary as the temperature rises, the joint become stronger. We can see from this experiment, the improvement of a metal’s strength is controlling by the grain size. We have to keep the grain sizes in minimum to make sure the joint is strong enough; therefore, optimum temperature must be examined through this experiment. Since a smaller grain size usually enhances mechanical properties, such as toughness and tensile strength, these metals often must be heated that just above critical temperature. Other than that, tensile strength of base metal also showing changes which keep increasing upon rise in temperature.

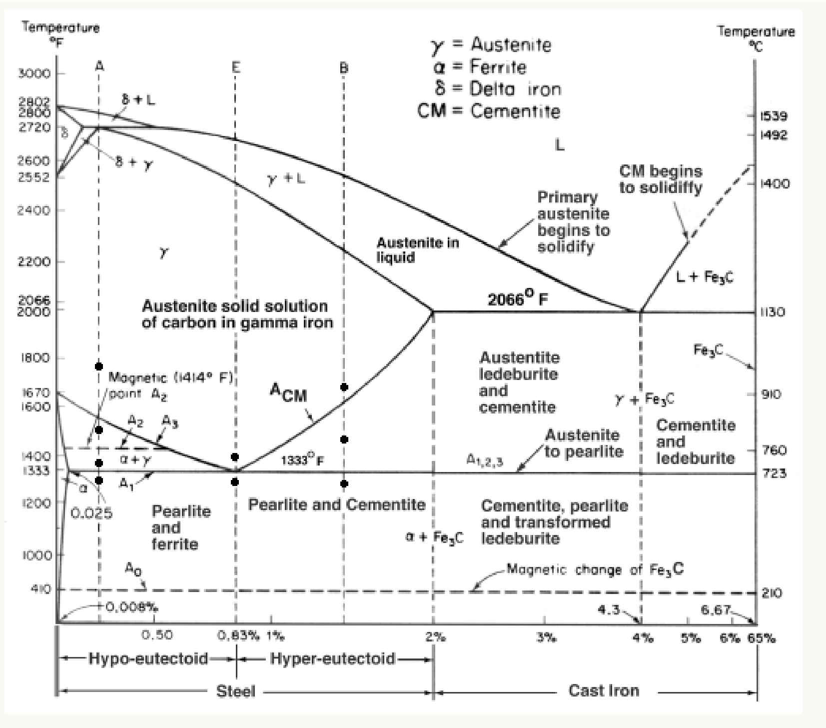


Figure 1 Iron-Carbon Phase Diagram

Figure 1 above would describes the iron-carbon system of alloys, discloses the phases compositions and their transformations occur during cooling or heating. Specimen used for this experiment has not more than 0.03% of carbon, as observed in ambient temperature up until 700 °C is perlite+ferrite. When ferrite forms, it is usually along HAZ grain boundaries which will restrict grain growth and minimize HAZ cracking [15]. Meanwhile as temperature increasing, the specimen at 900ºC started to become ferritic-austenitic as it lies on lines between ferrite and austenite.

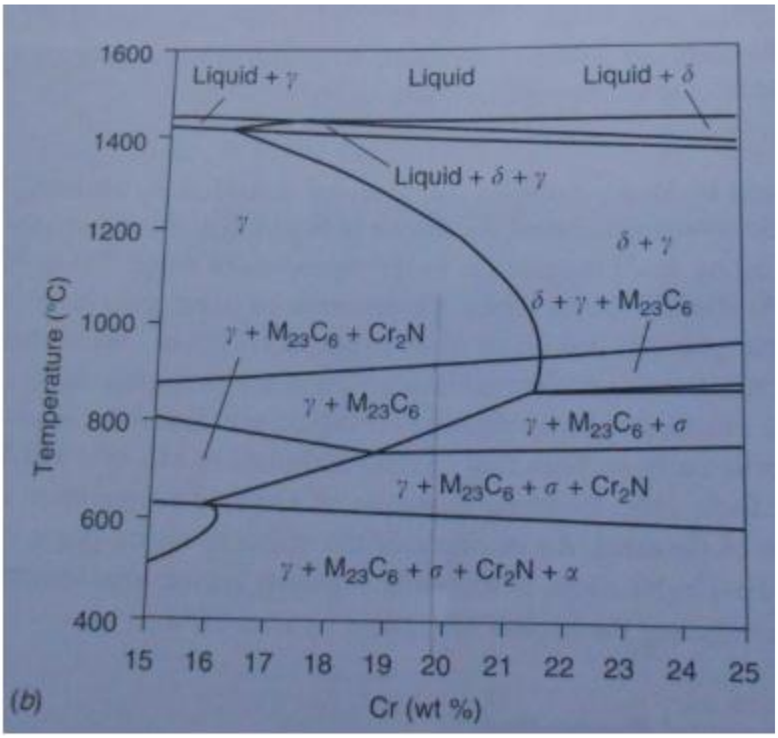


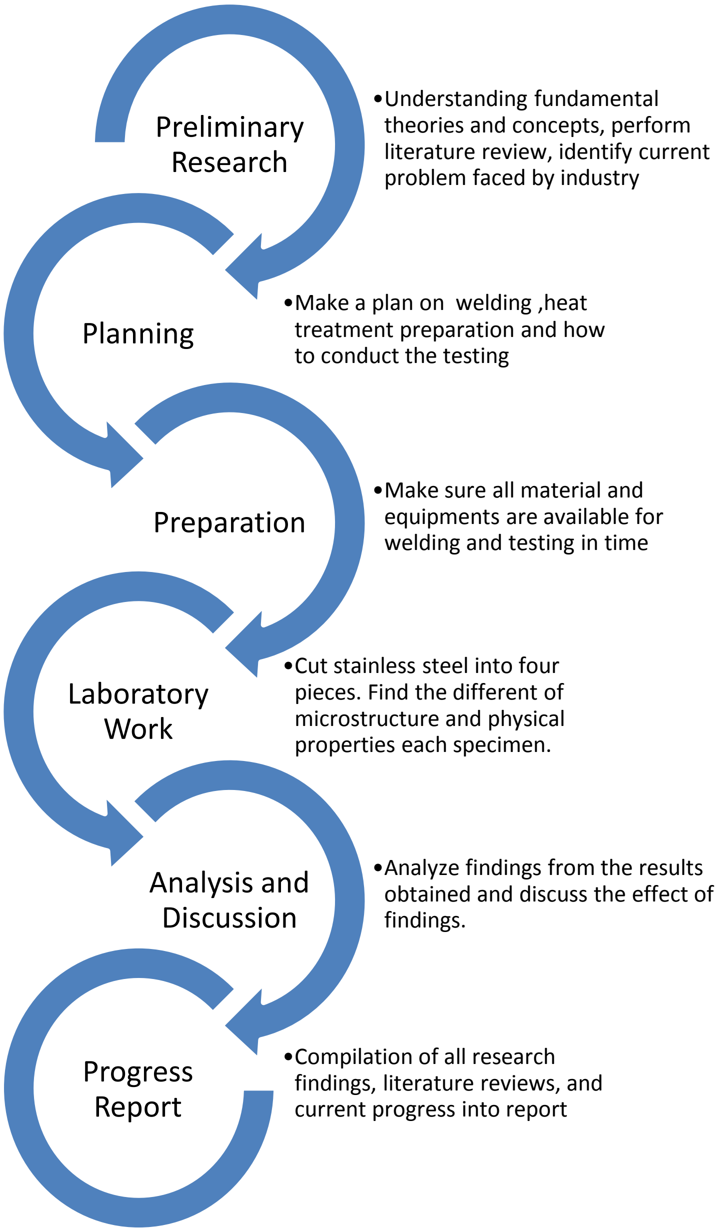
Figure 2 Phase diagrams using ThermoCalc , variable Cr

As temperature of heat treatment increases, microstructures of metal formed as shown in Figure 2, $M_{23}C_6$ + Cr_2N which would cause reduction of fracture toughness. At 900ºC, Figure 2 shows that only $M_{23}C_6$ which would be the reason of brittle structure of metal however would increase strength and hardness of materials [16].

In some research paper, they show the microstructure of base metal of with and without treatment, which shows the grain refinement become more ductile. This is the reason why this experimental research has come out. Further investigation of this research will be done after experiment is completed.

CHAPTER 3: METHODOLOGY/ PROJECT WORK

3.1 RESEARCH METHODOLOGY



3.2 KEY PROJECT MILESTONE

Conducting a project needs a target to mark the completion of a phase to another phase. Value of scheduling is to ensure the project is on track and completed in the time. In addition, it also helps to keep track the progress of project.

Table 1 Key milestone

Week	Work Progress
1-2	Welding joint of specimen and cut specimen into four different plates
3-4	Specimen undergo heat treatment for 300^{o}C, 600^{o}C and 900^{o}C
5-6	Hardness Testing and Microstructure Testing
7	Preparation of tensile test and submission of progress report
8-9	Tensile Test and preparation of SEDEX
10	Pre-SEDEX
11	Submission final draft
12	Submission Technical Paper
13-14	Preparation for VIVA and VIVA session
15	Submission of final report

3.3 PROJECT TIMELINE (GANTT CHART)

Table 2: Gantt Chart

No	**Detail Work**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
1	Welding joint of specimen and cut specimen															
2	Post Weld Heat Treatment (PWHT)															
3	Hardness Testing															
4	Microstructure Testing															
5	Preparation of Progress report															
6	Submit Progress Report															
7	Preparation of tensile testing															
8	Tensile Testing															
9	Preparation of PRE-Sedex															
10	PRE-Sedex															
11	Submit Draft Final Report															
12	Submit Technical Paper															
13	VIVA															
14	Submission of final report (hardbound)															

3.4 FLOW CHART

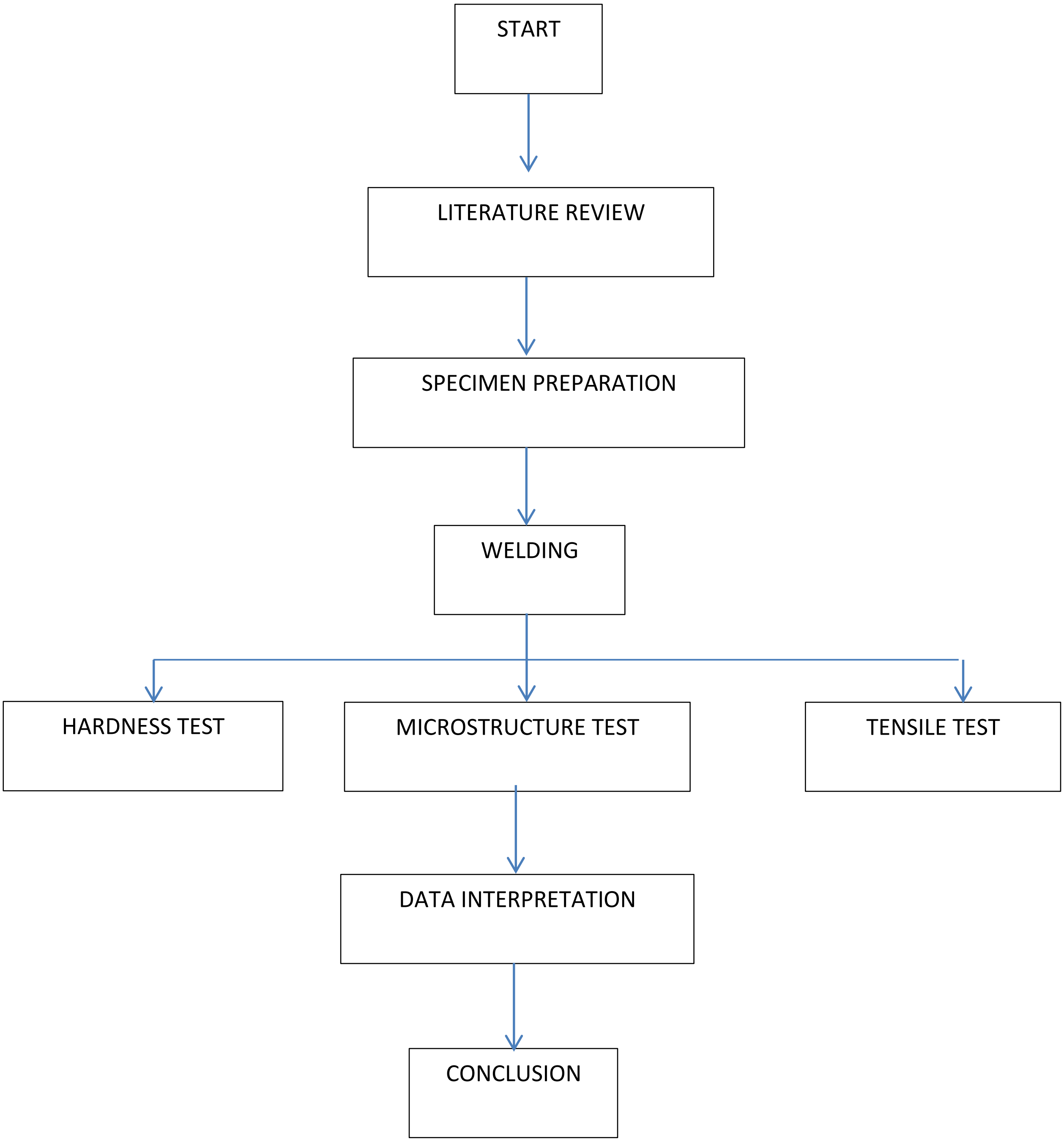


Figure 3 Flow Chart

3.5 MATERIAL CHOSEN (WELD METAL AND BASE METAL)

Austenitic stainless steel is selected for carrying out the experimental analysis because it is very malleable and workable. Austenitic stainless steel that has been chosen is 316L because it has low cost, easy availability in the market. Besides, L represent the presence of carbon will be not more than 0.03% which will eliminate the risk of dropping corrosion resistance when exposed to some temperature for a long period.

Four samples plates (each cut into 4 pieces) of austenitic stainless steel; material specification as below. The dimension of specimen will follow the ASTM standard of testing:

Material : Austenitic stainless steel (316L)
Thickness : 5 mm
Size : 5mm x 400mm x 250mm
No. of pieces : 8

For this experiment, ER308LSi is used which it is filler rod for MIG process. Filler rod specification is as below:

Type : ER308LSi
Heat No : E42126
Specification : AWS A5 ER308LSi
Size : 0.8 mm

Chemical composition of the base metal and weld metal as below:

Table 3: Chemical composition of weld metal and base metal

	C	**Si**	**Mn**	**P**	**S**	**Ni**	**Cr**	**Mo**
SS 316L	0.0187	0.06	1.05	0.022	0.004	10.4	16.87	2.1
ER308LSi	0.016	0.88	2.1	0.02	0.008	10.0	19.9	0.16

3.6 PREPARATION FOR WELDING AND HEAT TREATMENT PROCESS

A. Before start welding, make sure all things are properly setup. It is necessary to do bevel to make sure the weld pool to form in. The metal need to be clean and must be grinding down the edges as below Figure 4. Welding process which MIG/GMAW is been scheduled for two joints of 316L.

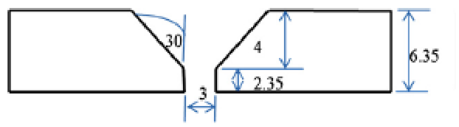


Figure 4 Welding configuration (bevel)

All joints will be welded using same speed, current, and work angle weld. This is to make sure all welding joints have same quality of weld.

Table 4 : Current, Voltage and Work angle GMAW

Current (A)	Voltage (V)	Work Angle
70	18	90^o

B. After all welding processes done, the two joints were cut into four pieces which follow tensile standard. The plate was cut into dogbone shape as preparation for tensile test. Size as below:

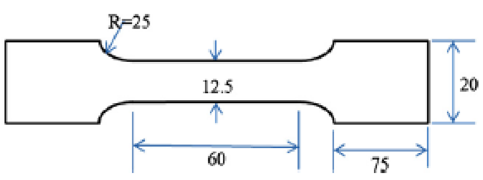


Figure 5 Dogbone shape

However, for microstructure testing and hardness, the specimens were cut into small pieces, each 25mm length, as Figure 6 below. All the specimens that had been cut will be mounted using mounting machine.

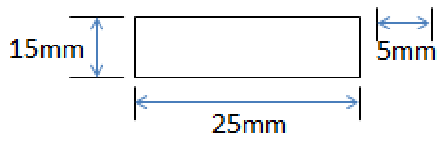


Figure 6 Size specimen for microstructure and hardness

To study the influence of post weld heat treatment (PWHT) on level of microstructure and mechanical properties of the specimen, the sample was subjected to heat treatment process for half an hour and cooling at ambient temperature. Temperatures of heat treatment and labeling for the specimen are as below:

Table 5: Temperature of PWHT

Label of specimen		Temperature (°C)
2A	3A	No treatment
2B	3B	300
2C	3C	600
2D	3D	900

All specimens had undergo heat treatment using CWF 13/13 furnace which has maximum heating up to 1300°C. For this experiment, the metal which has same treatment temperature will be heating in one time; 2B and 3B microstructure specimen and 2B and 3B tensile specimen been heating at same time in one furnace.

3.7 EXPERIMENTAL PROCEDURES

To ensure the results of experiment are defect-free, all specimens have been grind and polish to make sure there is no uneven surface during hardness and microstructure testing. The uneven surface will affect the result of experiment; hardness will become lower on uneven surface.

For SEM microstructure testing, the samples were polished to make sure it had smooth surface before testing. The samples also need to be etch using right solution which this experiment used Vilella's Reagent; 45ml glycerol, 15ml nitric acid and 30ml hydrochloric acid. Etching solution will able to expose the grain boundaries. Surface of metal will be etched between seconds to minutes until the surface become dull. This step was taken for microstructure test to study the behavior of each sample.

The hardness across the weld surface was measured using Rockwell hardness tester. The hardness profile was measured at the center of the surface as shown in Figure 7. Before using hardness tester, it was calibrated using calibration block. We have used 1/16" ball and using Brinell Hardness (HRB scale).

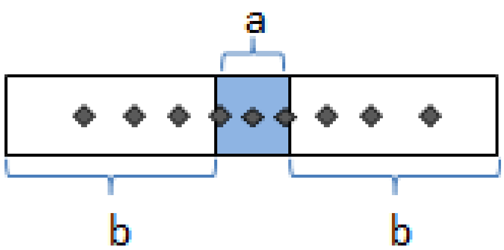


Figure 7 Schematic diagram shows hardness profile along welded plate (a) weld and (b) base metal

Tensile testing was carried out in conformity with ASTM standards [14]. Tensile test will be done using tensile machine on welded and treated specimen at room temperature. Machine used for tensile test is Universal Testing Machine 100kN model GOTEC.

All testing will be conducted according to standard, ensure all result valid and can be compared to previous research paper.

3.8 STANDARDS FOR TESTING

ASTM E8 (Tensile Test)

This is standard test methods for tension testing of metallic material. The significance of tension test according to the standards is to provide information on the strength and ductility of material. The results of tension tests of specimens' machines to standardize dimension from selected portion of material may not totally represent the strength and ductility properties entire end product.

This test method covers the tension testing of metallic materials in any form at room temperature. The dimension of specimen to be tested also included in this standards.

ASTM E18 (Hardness Test)

This test method describes the setup and procedure for determining the Rockwell Hardness. The choice of hardness scale is based on the material to be tested.

The apparatus consists of either a conical tip diamond indenter or a tungsten carbide ball indenter mounted under a force sensor on a motor-driven vertical positioning carriage. The specimen is mounted on either a stationary table or a linear stage directly under the indenter. A capacitance displacement sensor is used to measure the depth of penetration.

ASTM 112 (Microstructure Test)

These test methods cover procedures for estimating and rules for expressing the average grain size of all metals consisting entirely, or principally, of a single phase. The grain size of specimens with two phases, or a phase and a constituent, can be measured using a combination of two methods, a measurement of the volume fraction of the phase and an intercept count.

This standard also covers the measurement the average grain size and includes the comparison procedure. Besides, it used to determine the average grain size of specimen with a distribution of grain areas, diameters or intercept length.

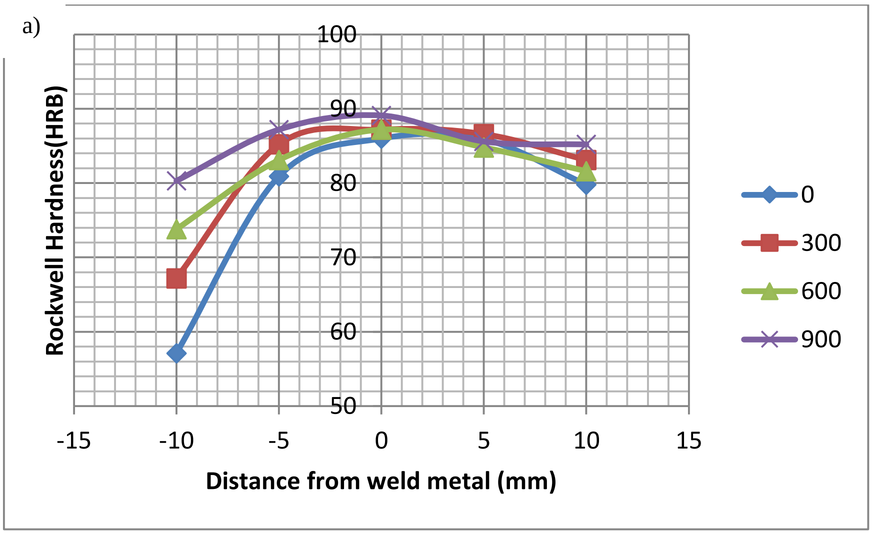
CHAPTER 4: RESULT AND DISCUSSION

4.1 HARDNESS TEST

Hardness test were performed to characterize the Rockwell hardness (HRB) profile along the direction of weld. Figure 6 illustrates the hardness profile of MIG welded 316L stainless steel. It shows the effect of annealing temperature on the hardness of weld metal. From the graph obtained, we can see that specimen with 900 ^{o}C has the higher hardness among the other temperature. Theoretically, higher post weld heat treatment in some cases will effectively relieve residual stresses but at this range, chromium carbides form rapidly in this temperature range so special care should be taken. However, from graph obtained 300^{o}C at -10 x-axis point, the hardness is lower than 600^{o}C. As the point is near to the middle which HAZ and weld area, 300^{o}C has higher hardness compared to 600^{o}C. It shows that it is not necessary that if temperature increasing, hardness would increase. Meanwhile, the lowest hardness was without heat treatment.

From Figure 8(b), we can see that weld metal has the higher hardness compared to base metal because of chromium content about 19.0% which was higher than base metal; as shown chemical composition in methodology. It is generally shows that chromium content would increase hardenability.

a)



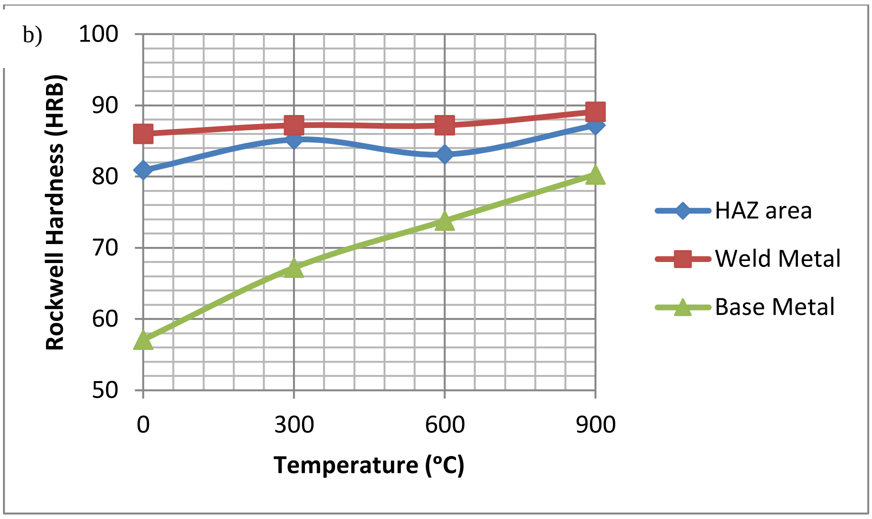
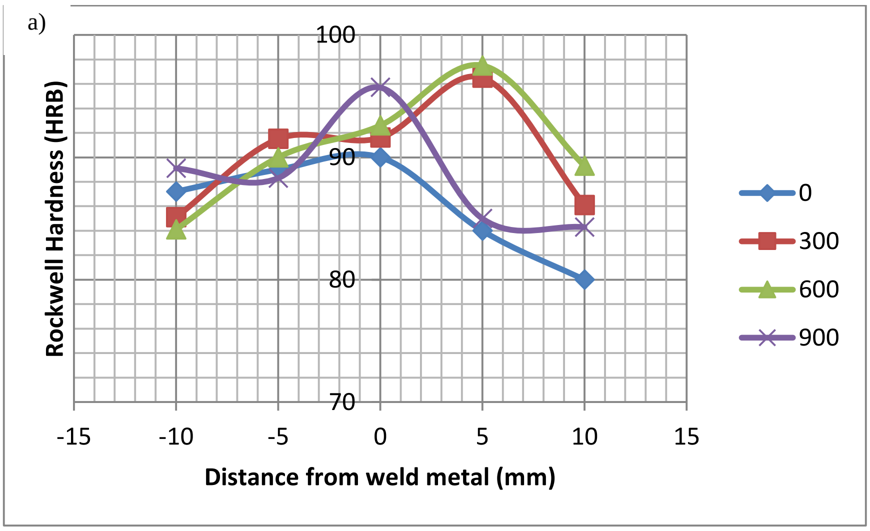


Figure 8 Hardness profile for four layer weld (a) distance from weld metal (b) HAZ, weld metal and base metal

Below graph shows different result from previous one which generally specimen which undergo treatment 600^{o}C generally has higher hardness compared to others. However at weld metal, specimen 900^{o}C has higher hardness compared to other specimen. The differences of result may because of different layer of welding which previous is four layer of welding and this is three layer welding. The different may happen because of exposed to different temperature during welding.

However, Figure 9(b) shows same result which, base metal is much lower than HAZ area and weld metal.



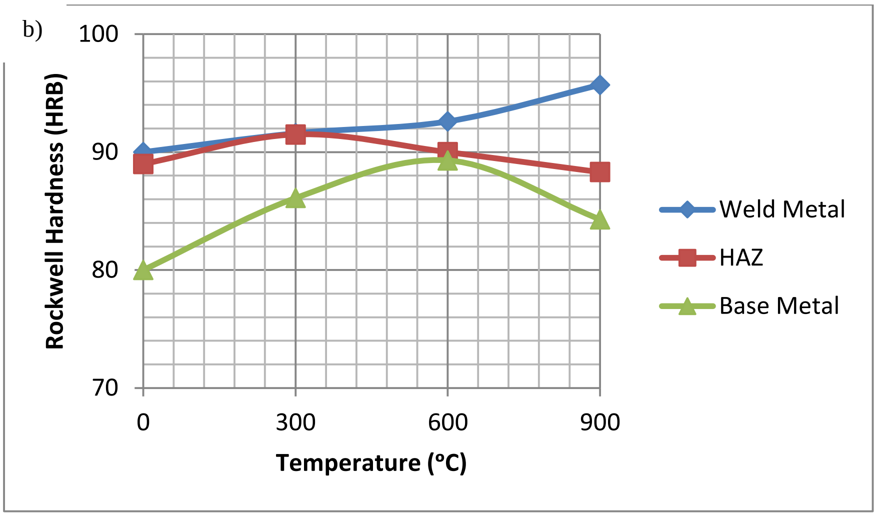


Figure 9 Hardness profile for three layer weld (a) distance from weld metal (b) HAZ, weld metal and base metal

4.2 SEM MICROSCOPE TEST

The microstructure of 316L steel before heat treatment as shown in Figure 8 shows grain boundaries of weld metal are increasing which can increase the hardness of metal. It shows why hardness of 900^{o}C in the hardness test is the highest. However, we can see chromium carbide form in Figure 10(a) is more than the other specimen. Chromium carbide will lead to rapid corrosion and sensitize the material. This will lead to loss of toughness and embrittlement. However, porosity at 600 ^{o}C shown and this is answer why it has lower toughness than 300^{o}C in previous page.

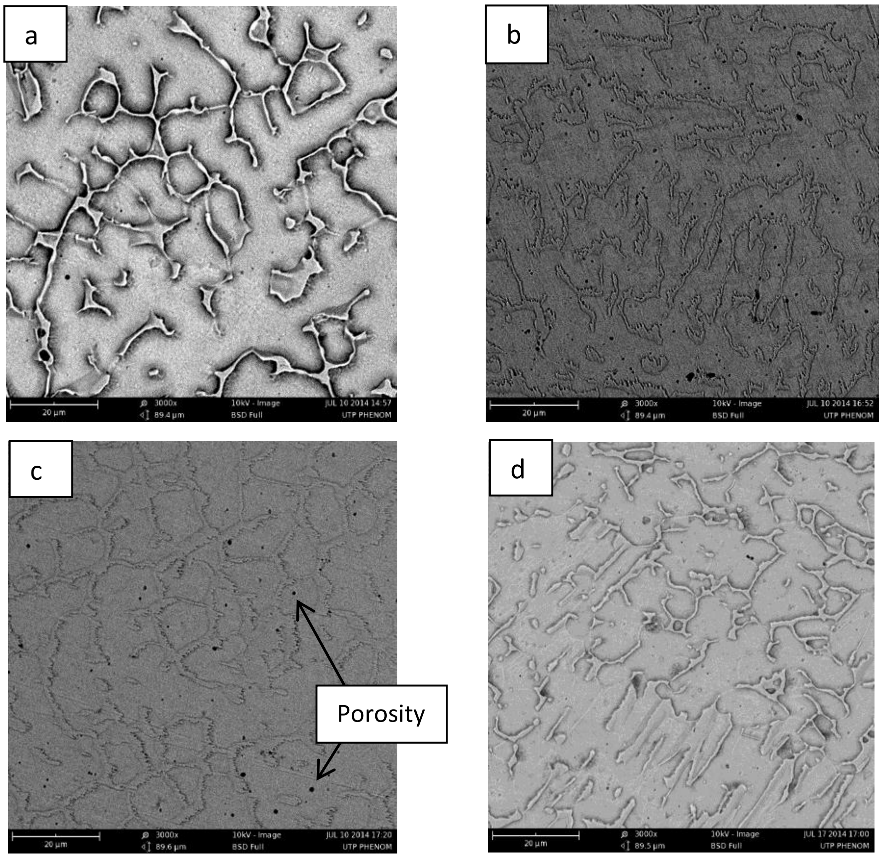


Figure 10 Microstructure SEM for four layer weld (a) without heat treatment (b) 300^{o}C (c) 600^{o}C and (d) 900^{o}C

Figure 11 shows that grain boundaries increasing from specimen without heat treatment to 900°C heat treatment. Below figure shows more on migration of grain boundaries which happen at 600°C and 900°C. This arrangement of microstructure shows why hardness profile for 600°C is generally high because 600°C shows larger grain boundaries.

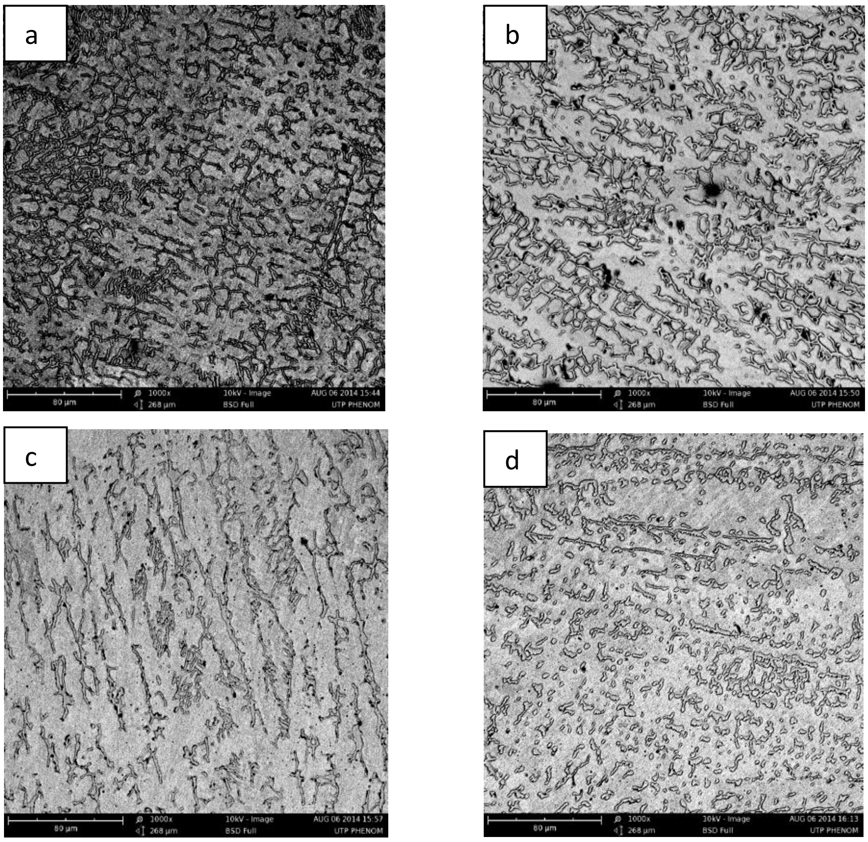
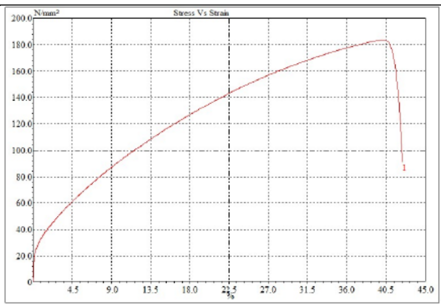
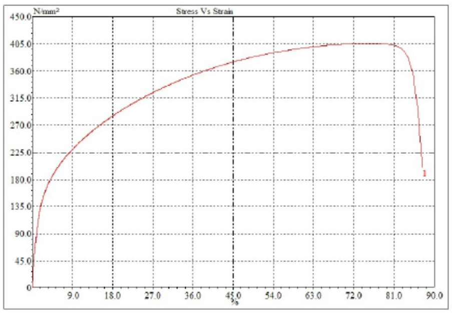
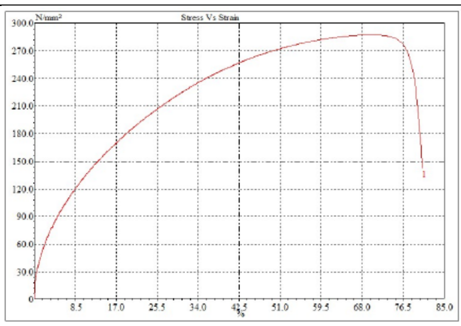


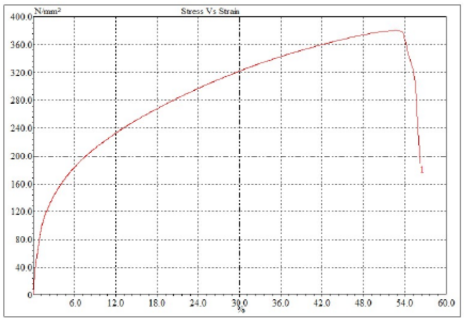
Figure 11 Microstructure SEM for three layer weld (a) without heat treatment (b) 300°C (c) 600°C and (d) 900°C

4.3 TENSILE TEST

Table 6 shows that tensile strength without heat treatment is the lowest because as previous page shows that the grain boundaries of this specimen are smaller than the others. Besides, chromium carbide will result to reduction of tensile strength.. Besides, for specimen temperature 600^{o}C shows second lower than because of its porosity. However, elongation of specimen shows that 900^{o}C has second lower than without heat treatment because it has highest toughness and it is brittle. Figure 12 below shows where fracture on specimen happen.

Table 6 : Tensile Strength for Four Layer

Label	Stress-Strain curve	Tensile Strength (N/mm^2)	Yield Strength (N/mm^2)	Elongation (%)
0		183.46	183.4	10.6
300		406.1	406.1	21.8
600		287.32	287.32	20.1

900		380.73	380.6	14

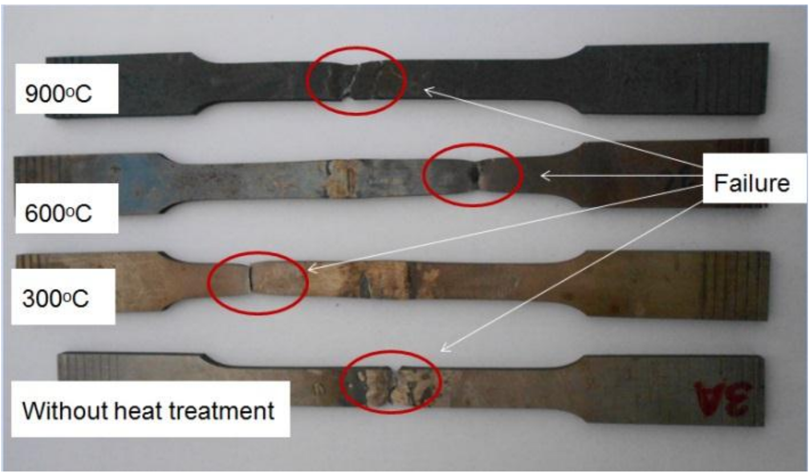
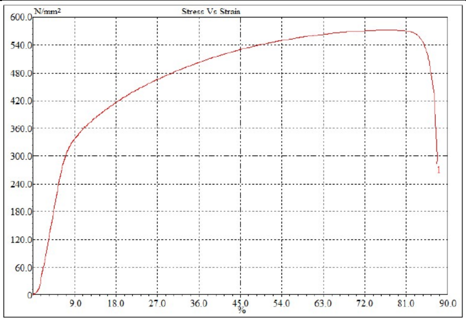
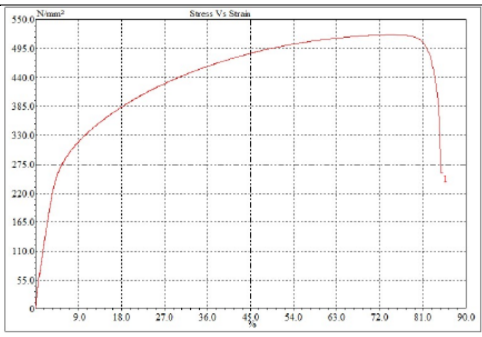
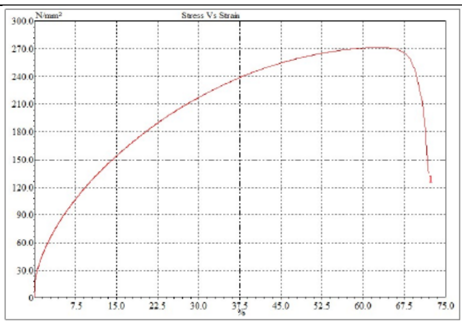
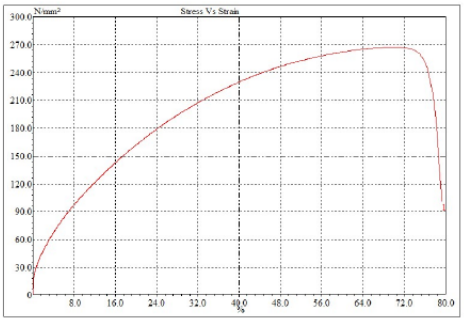


Figure 12 Fracture for four layer weld

Table 7 shows that tensile strength without heat treatment is the highest. However, the tensile strength for 900°C is the lowest because of it fractured at the base metal which has lowest hardness. Figure 13 shows fracture at the metal.

Table 7 : Tensile Strength for Three Layer

Label	Stress-Strain curve	Tensile Strength (N/mm^2)	Yield Strength (N/mm^2)	Elongation (%)
0		572.7	572.73	21.8
300		521.11	521.11	21.3
600		271.57	271.5	17.9

900		267.45	267.4	19.8

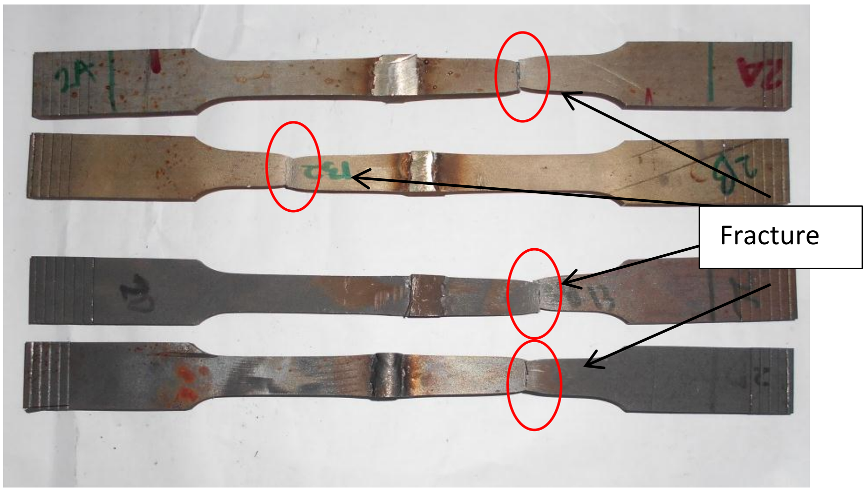


Figure 13 Fracture for three layer weld

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

As the conclusion, this study is important to be conducted because by doing the experiment, we can determine the difference on base metal microstructure and mechanical properties according to the temperature changes. Experimental procedure for this project is preparing four sample of stainless steel to joint together by using GMAW. After weld those four samples into two joints, the sample will be cut into four same size specimens. All specimens will undergo heat treatment using different temperature. After the specimens undergo two out of three testing, we can see the difference before and after heat treatment on the physical properties and microstructure of weld metal. As we can see also, we cannot assume that the higher temperature is the best temperature for heat treatment because we have to see from all aspects involve such as size of grain boundaries. Other than that, early testing that had been made shows that hardness values measured before and after heat treatment showed insignificant variations. It is not necessary that higher hardness has the higher tensile strength because of different brittleness. We can see the different result between three layers and four layers of welding; it shows that temperature during welding also effect the result of experiment. If we analyse the tensile test, we can see that three layer welding has the highest tensile strength than four layers. Besides, the fractures in three layer welding occur at the base metal shows that the weld metal is strong enough. We can conclude from both experiment made that increasing temperature will increase the toughness of material, increase grain boundaries. On top of that, the formation of $M_{23}C_6$ and Cr_2N would also be a reason increasing of toughness as well as brittle structure of metal.

5.2 RECOMMENDATION

GMAW has been chosen for this research because it is one of welding processes that has high quality weld and can be produce faster. Besides, the welder must have experience in handling the machine. If not, the welding will not have same result along the joint. In addition, post weld heat also has been done because it is proved from research that it can improve composition of materials. Four temperatures set for PWHT experiment for each specimen. To avoid any drift result to the experiment, this experiment will be repeating three times to make sure the result is reliable. The tests that will be conducted are hardness, impact test and tensile test. Research must be done before doing this test in order to get best result. There are some obstacles faced during research done which furnace with long 450mm has broken down and the action must be immediately taken to repair the furnace. All equipment must be maintained and check at least once in three months, this will make sure convenience for all users.

CHAPTER 6: REFERENCES

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CHAPTER 7: APPENDICES

Table 8 : Previous Key Milestone

	Work Progress
Week 1 and Week 2	Selection of project topic
Week 3 to Week 5	Understand the project topic and find suitable specimen in market
Week 6 to Week 8	Draft Extended Proposal and Proposal Defense
Week 9 to Week 12	Conduct Experiment
Week 13 and Week 14	Interim Report Submission

Table 9 : Previous Gantt Chart FYP 1

No	**Detail Work**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	Selection of Project Topic														
2	Understand the project title and objectives														
3	Define scope of project for the first phase														
4	Study previous research paper and journal														
5	Preparing Extended Proposal														
6	Submission of Extended Proposal														
7	Find specimen (316L) available in market														
8	Preparation of proposal defense														
9	Proposal defense														
10	Prepare interim report														
11	Welding joint of specimen and cut specimen into four different plate														
12	Microstructure Testing														
13	Post Weld Heat Treatment (PWHT)														
14	Hardness Testing														
15	Submit interim report														

COMMON MATERIAL GRADES

Specification	Description	UNS No.	Category No.	“P” Number
AS 3678-250	Plain carbon steel plate	-	A1	P1
AS 3678-350	Plain carbon steel plate	-	A1	P1
AS 1548-7-430	Carbon steel boiler plate	-	A1	P1
AS 1548-7-460	Carbon steel boiler plate	-	A1	P1
AS 1548-5-490	Carbon steel boiler plate	-	A2	P1
AS 1548-7-490	Carbon steel boiler plate	-	A2	P1
ASTM A106 GRB	Plain carbon steel pipe	K03006	A1	P1
API 5L GRB	Plain carbon steel pipe	-	A1	P1
ASTM A105N	Plain carbon steel flanges	K03504	A1	P1
ASTM A234 WPB	Plain carbon steel fittings	K03006	A1	P1

ASTM A240-304L	Austenitic stainless steel plate	S30403	K	P8
ASTM A240-316L	Austenitic stainless steel plate	S31603	K	P8
ASTM A312-TP304L	Austenitic stainless steel pipe	S30403	K	P8
ASTM A312-TP316L	Austenitic stainless steel pipe	S31603	K	P8
ASTM A182-F304L	Austenitic stainless steel fittings	S30403	K	P8
ASTM A182-F316L	Austenitic stainless steel fittings	S31603	K	P8

UNS: International Systems Organisation (ISO) - Unified Numbering System.

Category Number: Australian Standards (AS) - Material Grouping Number.

"P" Number: American Society of Mechanical Engineers (ASME) - Material Grouping Number.

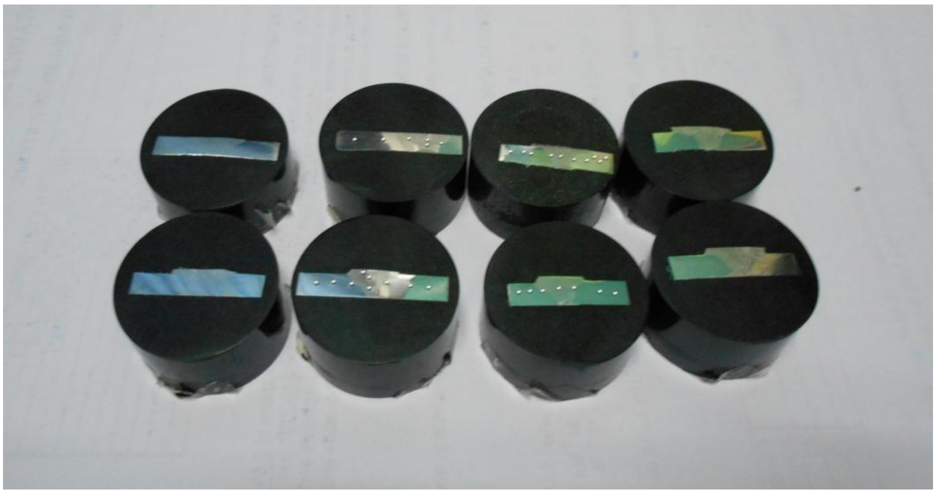

Figure 14 Mounting

Figure 15 (a) Furnace (b) MIG machine (c) Welder