Study on the Essential Variable of Welding Procedure Specification (WPS) of Fillet Weld

By

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Dissertation submitted in partial fulfillment of
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Bachelor of Engineering (Hons)
(Mechanical Engineering)

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Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Mechanical Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
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January 2009

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 in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

KHALED HAMDAN

ABSTRACT

The technique of welding with the right variable of welding procedure is important in determining the integrity of the weld. The objective of the project is to study the effect of the manipulated essential variable of Welding Procedure Specification of fillet weld on the structure which for this project is two plate of steel based on the established welding procedure specification. The challenge in this project is to perform the tests on the welding specimen to study the effect of manipulated essential variable of Welding Procedure Specification (WPS). The welding voltage of welding procedure was manipulated. Subsequently, mechanical test and non-destructive test were done to analyze the fillet welds and the findings of the study were revealed. From the results, the higher voltage could decrease the brittleness of the weld and increase its ductility. It also can reduce the residual stress presence in the weld. Secondly, the higher voltage can make the weld have deeper fusion.

ACKNOWLEDGEMENT

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TABLE OF CONTENTS

CERTIFICATION			i
ABSTRACT			1
ACKNOWLEDGEMENT			2
CHAPTER 1:	**INTRODUCTION**		7
	1.1	Background of Study	7
	1.2	Problem Statement	8
	1.3	Objectives and Scope of Study	8
CHAPTER 2:	**LITERATURE REVIEW**		9
	2.1	Introduction	9
	2.2	Material	9
	2.3	Welding Procedure	11
	2.4	Weld Testing	12
	2.4.1	Non-destructive Testing	13
	2.4.2	Mechanical Testing	13
	2.5	Welding Voltage in Metal Inert Gas	14
	2.6	Direct Effect of Arc Voltage in Heat-Affected Zone (HAZ) Characteristics in Submerged Arc Welding (SAW) of Structural Pipes	15
	2.7	Fume Composition in Metal Active Gas Welding	16
CHAPTER 3:	**METHODOLOGY**		17
	3.1	Project Experiment	17
	3.1.1	Visual Examination	17
	3.1.2	Non-Destructive Testing for Surface Crack Detection	18
	3.1.3	Mechanical Testing	21
	3.2	Tools and Equipment	25
CHAPTER 4:	**RESULTS AND DISCUSSION**		27
	4.1	Results	27
	4.1.1	Cutting the Steel	27
	4.1.2	Welding the Plate	28
	4.1.3	Visual Examination	30
	4.1.4	Non-Destructive Testing for Surface Crack Detection	33
	4.1.5	Mechanical Testing	44
	4.2	Discussion	53
	4.2.1	Visual Examination	53

4.2.2 Non-Destructive Testing for Surface Crack Detection 53
4.2.3 Mechanical Testing . . . 54

CHAPTER 5: **CONCLUSION AND RECOMMENDATION** 55
5.1 Conclusion 55
5.2 Recommendations . . . 55

REFERENCES 56

APPENDICES 57

LIST OF FIGURES

Figure 2.1	Direct effect of arc voltage on the width of the different HAZ regions	15
Figure 2.2	Effect of voltage on fume composition for different wire diameter MAG welding of stainless steel	16
Figure 4.1	Cutting with plasma cutter	27
Figure 4.2	Cutting with band saw	27
Figure 4.3	Welded plate with welding voltage, 90V (PLATE 1)	28
Figure 4.4	Welded plate with welding voltage, 120V (PLATE 2)	28
Figure 4.5	Welded plate with welding voltage, 150V (PLATE 3)	29
Figure 4.6	Visual examinations for PLATE 1	30
Figure 4.7	Visual examinations for PLATE 2	31
Figure 4.8	Visual examination for PLATE 3	32
Figure 4.9	Dye penetrant results for PLATE 1	33
Figure 4.10	Dye penetrant results for PLATE 2	34
Figure 4.11	Dye penetrant results for PLATE 3	35
Figure 4.12	Magnetic particle testing results for PLATE 1	36
Figure 4.13	Magnetic particle testing results for PLATE 2	37
Figure 4.14	Magnetic particle testing results for PLATE 3	38
Figure 4.19	Micro examinations result for base metal of PLATE 1	50
Figure 4.20	Micro examinations result for weld metal of PLATE 1	50
Figure 4.21	Micro examinations result for base metal of PLATE 2	51
Figure 4.22	Micro examinations result for weld metal of PLATE 2	51
Figure 4.23	Micro examinations result for base metal of PLATE 3	52
Figure 4.24	Micro examinations result for weld metal of PLATE 3	52

LIST OF TABLES

Table 2.1	Type of steel	9
Table 3.1	Form for magnetic particle and dye penetrant test result	20
Table 3.2	Form for vickers hardness test result	22
Table 3.3	Form for macro etch examination result	24
Table 4.1	Magnetic particle and dye penetrant test result for PLATE 1	39

Table 4.2	Magnetic particle and dye penetrant test result for PLATE 2	40
Table 4.3	Magnetic particle and dye penetrant test result for PLATE 3	41
Table 4.4	Vickers hardness test result for PLATE 1	44
Table 4.5	Vickers hardness test result for PLATE 2	45
Table 4.6	Vickers hardness test result for PLATE 3	46
Table 4.7	Macro etch examination result for PLATE 1	47
Table 4.8	Macro etch examination result for PLATE 2	48
Table 4.9	Macro etch examination result for PLATE 3	49

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

The fillet weld is used to make lap joints, corner joints, and T joints. As its symbol suggests, the fillet weld is roughly triangular in cross-section, although its shape is not always a right triangle or an isosceles triangle. Weld metal is deposited in a corner formed by the fit-up of the two members and penetrates and fuses with the base metal to form the joint. For this project, fillet welding will be performed on two plate of steel.

According to Unified Engineering Inc (2008)

In mechanical engineering, a fillet is a concave easing of an interior corner of a part design. The applications of the fillet are:

- Stress concentration is a problem of load-bearing mechanical parts which is reduced by employing fillets on points and lines of expected high stress. These features effectively make the parts more durable and capable of bearing larger loads.
- For considerations in aerodynamics, fillets are employed to reduce interference drag where aircraft components such as wings, struts, and other surfaces meet one another.
- For manufacturing, concave corners are sometimes filleted to allow the use of round-tipped end mills to cut out an area of a material. This has a *cycle time* benefit if the round mill is simultaneously being used to mill complex curved surfaces

1.2 PROBLEM STATEMENT

In industry, the Welding Procedure Specification (WPS) is being used to make fillet weld joint on the structure. The different values of essential variable (welding voltage) of WPS have the different effects on the quality of the weld.

1.3 OBJECTIVE AND SCOPE OF STUDY

The scopes of this research are:

- To perform visual examination on the structure
- To perform surface crack detection on the structure
- To perform macro examination (macro etch) on the structure
- To perform hardness test on the structure
- To perform micro examination(optical microscopy) on the structure

The objective of this work is to:

- Study on the effect of different value of essential variable of Welding Procedure Specification (WPS) of fillet weld joint on the two plates.

In this project, the essential variable of Welding Procedure Specification (WPS) that will be manipulated is the welding voltage. To achieve the objective, several Mechanical Testing and Non-destructive Testing will be performed.

CHAPTER 2
LITERATURE REVIEW

2.1 INTRODUCTION

Welding is a fabrication process that joins materials, usually metals or thermoplastics, by causing coalescence. This is often done by melting the work pieces and adding a filler material to form a pool of molten material (the *weld puddle*) that cools to become a strong joint, with pressure sometimes used in conjunction with heat, or by itself, to produce the weld. This is in contrast with soldering and brazing, which involve melting a lower-melting-point material between the work pieces to form a bond between them, without melting the work pieces.

2.2 MATERIAL

In Oil & Gas industry, there are several types of steel that being used. Below is table of the type of the steel (Carigali-PTTEPI, 2006)

Table 2.1 Type of steel

Steel Type	Description	Minimum Yield Strength (MPa	Minimum Tensile Strength (MPa)
I	Primary Structural Steel – High Strength	345	450
II	Primary Structural Steel – High Strength With Through Thickness Properties	345	450
III	Primary Structural Steel – Mild Steel	248	430
IV	Primary Structural Steel – Mild Steel With Through Thickness Properties	248	430
V	Secondary Structural Steel	248	430

The following describes the classification of structural steels:

TYPE I STEEL: Primary Structural Steel – High Strength

Primary structural steel – high strength, is steel with a minimum yield strength of 345 MPa and is used in members essential to the overall integrity of the structure and for other structural members of importance to the operational safety of the structure. TYPE I steel may be grades ASTM A572 Gr.50, API 2H Gr.50, API 5L X Gr.52 or equivalent.

TYPE II STEEL: Primary Structural Steel – High Strength With Through Thickness Properties

Primary Structural Steel – High Strength With Through Thickness Properties, is steel with minimum yield strength of 345 MPa and is used in members essential to the overall integrity of the structure, where stress concentration are high and where the stresses in the thickness direction may lead to lamellar tearing. TYPE II steel may be grades ASTM A572 Gr.50, API 2H Gr.50, API 5L X Gr.52 or equivalent.

TYPE III STEEL: Primary Structural Steel – Mild Steel

Primary Structural Steel – Mild Steel, is steel with a specified yield strength between 248 MPa and 345 MPa and is used in members essential to the overall integrity of the structure and for other structural members of importance to the operational safety of the structure. TYPE III steel may be grades ASTM A36, ASTM A106B, API 5I Gr.B or equivalent.

TYPE IV STEEL: Primary Structural Steel – Mild Steel With Through Thickness Properties

Primary Structural Steel – Mild Steel With Through Thickness Properties is steel with specified yield strength between 248 MPa and 345 MPa and is used in members essential to the overall integrity of the structure, where stress concentrations are high and where the stresses in the thickness direction may lead to lamellar tearing. TYPE IV steel may be grades ASTM A36, ASTM A106B, API 5L Gr.B or equivalent.

TYPE V STEEL: Secondary Structural Steel

Secondary structural steel is steel used in members not essential to the overall integrity of the structure and/or the operational safety.

For this project, Type IV (ASTM A36) Steel has been chosen as the metal that will be welded because its feasibility with the project.

2.3 WELDING PROCEDURE

Producing a welding procedure involves:

- Planning the tasks
- Collecting the data
- Writing a procedure for use of for trial
- Making a test welds
- Evaluating the results
- Approving the procedure
- Preparing the documentation

In most codes reference is made to how the procedure is to be devised and whether approval of these procedures is required. The approach used for procedure approval depends on the code. Example codes:

- AWS D.1.1: Structural Steel Welding Code
- BS 2633: Class 1 welding of Steel Pipe Work
- API 1104: Welding of Pipelines
- BS 4515: Welding of Pipelines over 7 Bar

Other codes may not specifically deal with the requirement of a procedure but may contain information that may be used in writing a weld procedure

- EN 1011 Process of Arc Welding Steels

Components of a welding procedure:

- Parent material
- Welding process
- Welding Consumables

- Welding Position
- Welding Variables
- Thermal heat treatments

Approving the procedure:

- When the data has been collected, the procedure must be validated by producing a test weld, *weld procedure test (WPT)*.
- A number of standards provide information with regards to approving a procedure, but normally this will require the WPT to be tested by NDT and mechanical testing.
- The locations and tests required will be given in the applicable code or standard
- Most codes and standards provide a report format to record the results

2.4 WELD TESTING

All code test procedures to determine whether qualification welds meet their requirements. For groove welds, guided bend test specimens are cut from specific locations in the welded plates and bent in specified jigs. Because fillet welds do not readily lend themselves to guided bend tests, fillet welds are usually subjected to weld break tests or macro-etch test or both. In most cases testing include one or more of the following:

- Visual inspection
- Guided bend tests
- Tensile tests
- Fracture test
- Macro-etch test
- Micro tests
- Radiographic test

2.4.1 Non-destructive Testing

Nondestructive testing (NDT), is also called nondestructive examination (NDE) and nondestructive inspection (NDI), is testing that does not destroy the test object. NDE is vital for constructing and maintaining all types of components and structures. To detect different defects such as cracking and corrosion, there are different methods of testing available, such as X-ray (where cracks show up on the film) and ultrasound (where cracks show up as an echo blip on the screen). This article is aimed mainly at industrial NDT, but many of the methods described here can be used to test the human body. In fact methods from the medical field have often been adapted for industrial use, as was the case with Phased array ultrasonic and Computed radiography.

2.4.2 Mechanical Testing

Mechanical testing is the ultimate means by which the mechanical strength and toughness of a prepared test object can be determined by subjecting it to mechanical forces beyond the limits of its own mechanical resistance.

Destructive testing of welded joints is usually carried out to:

- Approve welding procedures
- Approve welders
- Production quality control
- Malleability- Can be deformed a great deal by compression before cracking
- Ductile- Can be deformed considerably by tension before it fractures
- Toughness - Ability to withstand bending without fracture
- Hardness - Measure of the resistance of a material to indentation

The following mechanical tests have units and are termed quantitative tests

- Tensile tests
- Toughness testing (Charpy, Izod)
- Hardness tests

The following mechanical tests have no units and are termed qualitative tests

- Macro testing
- Bend testing
- Fillet weld fracture testing
- Butt weld nick-break testing

2.5 WELDING VOLTAGE (ARC LENGTH) IN METAL INERT GAS (MIG)

The arc length is one of the most important variables in MIG that must be held under control. When all the variables such as the electrode composition and sizes, the type of shielding gas and the welding technique are held constant, the arc length is directly related to the arc voltage.

For example, normal arc voltage in carbon dioxide and helium is much higher than those obtained in argon. A long arc length disturbs the gas shield, the arc tends to wander and thus affect the bead surface of the bead and the penetration.

In MIG the arc voltage has a decide effect upon the penetration, the bead reinforcement and bead width. By increasing the arc voltage the weld becomes flatter and wider, the penetration increases until an optimum value of the voltage is reached, at which time it begins to decrease. High and low voltages cause an unstable arc.

Excessive voltage causes the formation of excessive spatter and porosity, in fillet welds it increases undercut and produces concave fillet welds subject to cracking. Low voltage produce narrower beads with greater convexity (high crown), but an excessive low voltage may cause porosity and overlapping at the edges of the weld bead (Weldability.com, 2008).

2.6 DIRECT EFFECT OF ARC VOLTAGE IN HEAT-AFFECTED ZONE (HAZ) CHARACTERISTICS IN SUBMERGED ARC WELDING (SAW) OF STRUCTURAL PIPES

Many investigators found voltage in a consumable electrode process has no significant effect on HAZ dimensions. In this investigation, it was found the effect of voltage is less than that of wire feed rate (F) on HAZ.

Figure 2.1 shows the effect of voltage (V) on the dimensions of different zones of the HAZ. From the figure 2.1, it is apparent widths of the weld interface (WI), grain refinement zone (GRZ) and HAZ increase slightly with the increase in V;grain growth zone (GGZ) increases significantly with the increase in V.

The reasons for these effects is the slight increase in heat input (heat input increases by about 4 kJ/cm) with the increases in V from, its lower limit (-2 level) to upper limit (+2 level). This slight increase in heat input reduces the cooling rate. Therefore, the dimensions of the different HAZ layers increase with the increase in V (V.Gunaraj and N. Murugan, 2008).

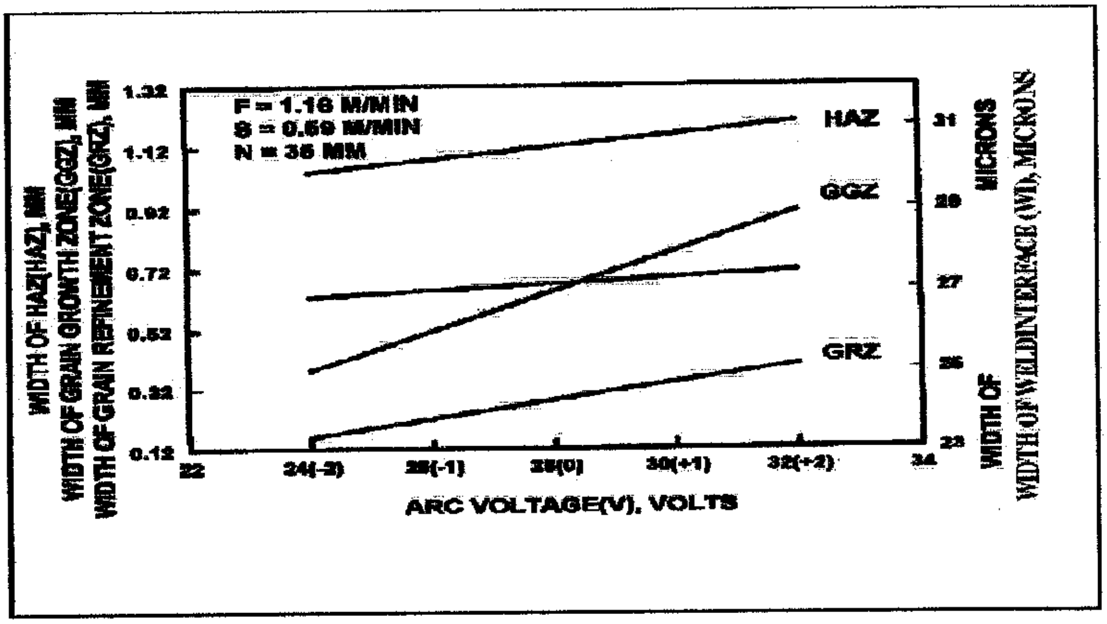


Figure 2.1 Direct effect of arc voltage on the width of the different HAZ regions (V.Gunaraj and N. Murugan, 2008)

2.7 FUME COMPOSITION IN METAL ACTIVE GAS (MAG) WELDING

Voltage was the parameter exerting the greatest effect on welding fume composition. But many of the parameters investigated had little effect at all, so that overall the variation in fume composition under different welding conditions was fairly small, typically less than 20 % (Weldability.com, 2008).

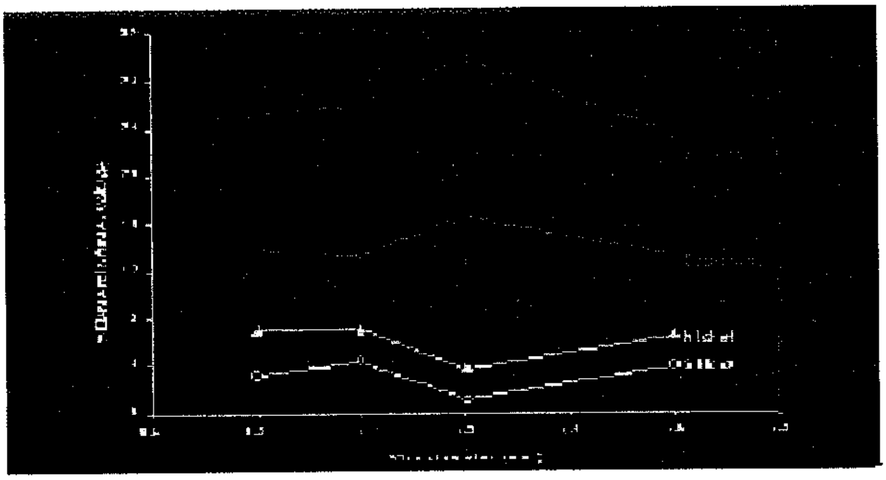


Figure 2.2 Effect of voltage on fume composition for different wire diameter MAG welding of stainless steel (Weldability.com, 2008)

CHAPTER 3
METHODOLOGY

3.1 PROJECT EXPERIMENT

The essential variable of welding procedure was manipulated and a set of pre-approval welding procedure was prepared for the manipulated variable to produce several fillet join weld. Below is the essential variable of welding procedure that was manipulated (Petronas, 1989).

- A change in welding voltage.

Other essential variables were made constant. Welding Procedure Specification (Appendix 2) contain all the important data before welding was done by the weldor. Subsequently, several tests were conducted to study the effect of the manipulated variable which was welding voltage. Tests conducted for this project are given in the following texts.

3.1.1 Visual Examination

After welding was complete, the weld must be visually inspected in accordance with the AWS D1.1, Structural Welding Code– Steel, Section 4.8.1 Visual inspection for acceptable qualification requires welds:

- Be free of cracks.
- Have all craters filled to the full cross-section of the weld.
- Have the face of the weld flush with the surface of the base metal.
- Undercut shall not exceed 1/32 inch (1 mm)
- Weld reinforcement shall not exceed 1/8 inch (3mm)
- The roots of the weld shall be inspected, and there shall be no evidence of cracks, incomplete fusion, or inadequate joint penetration. A concave root surface is permitted within the limits shown below, provided the total thickness is equal to or greater than that of the base metal.

- Maximum root surface concavity shall be 1/16 inch (1.6 mm) and the maximum melt-through shall be 1/8 inch (3 mm).

3.1.2 Non-destructive Testing for surface crack detection

a) Magnetic particle testing

Magnetic particle inspection processes are non-destructive methods for the detection of defects in ferrous materials

Procedure:

- Clean area to be tested
- Apply contrast paint
- Apply magnetisism to the component
- Apply ferro-magnetic ink to the component during magnetising
- Interpret the test area
- Post clean and de-magnatise if required

b) Ultrasonic testing

It is very short ultrasonic pulse-waves with center frequencies ranging from 0.1-15 MHz and occasionally up to 50 MHz are launched into materials to detect internal flaws or to characterize materials. The technique is also commonly used to determine the thickness of the test object, for example, to monitor pipe work corrosion.

Procedure:

- Surface and sub-surface detection
- This detection method uses high frequency sound waves, typically above 2MHz to pass through a material
- A probe is used which contains a piezo electric crystal to transmit and receive ultrasonic pulses and display the signals on a cathode ray tube or digital display
- The actual display relates to the time taken for the ultrasonic pulses to travel the distance to the interface and back

- An interface could be the back of a plate material or a defect
- For ultrasound to enter a material a couplant must be introduced between the probe and specimen

c) Dye penetrant inspection (DPI)

It also called liquid penetrant inspection (LPI), is a widely applied and low-cost inspection method used to locate surface-breaking defects in all non-porous materials (metals, plastics, or ceramics)

Procedure

Step 1 Pre-Cleaning

Ensure surface is very Clean normally with the use of a solvent

Step 2 Apply Penetrant

After the application of the penetrant the penetrant is normally left on the components surface for approximately 15 minutes (dwell time). The penetrant enters any defects that may be present by capillary action

Step 3 Clean off Penentrant

After sufficient penetration time (dwell time) has be given the penetrant is removed, care must be taken not to wash any penetrant out off any defects present

Step 4 Apply Developer

After the penetrant has been cleaned sufficiently a thin even layer of developer is applied. The developer acts as a contrast against the penetrant and allows for reverse capillary action to take place

Step 5 Inspection/Development Time

Inspection should take place immediately after the developer has been applied any defects present will show as a bleed out during development time. After full inspection has been carried out post cleaning is generally required.

Table 3.1 Form for magnetic particle and dye penetrant test result

<table>
<tr><td colspan="5">MAGNETIC PARTICLE AND DYE PENETRANT TEST</td></tr>
<tr><td colspan="3">Client:
Project:</td><td colspan="2">Inspection Date:
Location:
Specification:</td></tr>
<tr><td colspan="3">Material:
Welding Process:
Weld Prep.:</td><td colspan="2">Thickness:
Surface Condition:</td></tr>
<tr><td colspan="3">MAGNETIC PARTICLE INSPECTION</td><td colspan="2">DYE PENETRANT INSPECTION</td></tr>
<tr><td colspan="3">Base:
Media:
Equipment:
Magnetizing Current:</td><td colspan="2">Penetrant:
Remover:
Developer:</td></tr>
<tr><td>No.</td><td>Joint Reference</td><td>Interpretation</td><td>Result</td><td>Remark</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="3">NDT Inspector:</td><td colspan="2">Approved by:
Client's Rep:</td></tr>
</table>

3.1.3 Mechanical testing

The ultimate means by which the mechanical strength and toughness of a prepared test object can be determined by subjecting it to mechanical forces beyond the limits of its own mechanical resistance.

a) Vickers Hardness Testing

The Vickers hardness test was developed as an alternative method to measure the hardness of materials. The Vickers test is often easier to use than other hardness tests since the required calculations are independent of the size of the indenter, and the indenter can be used for all materials irrespective of hardness.

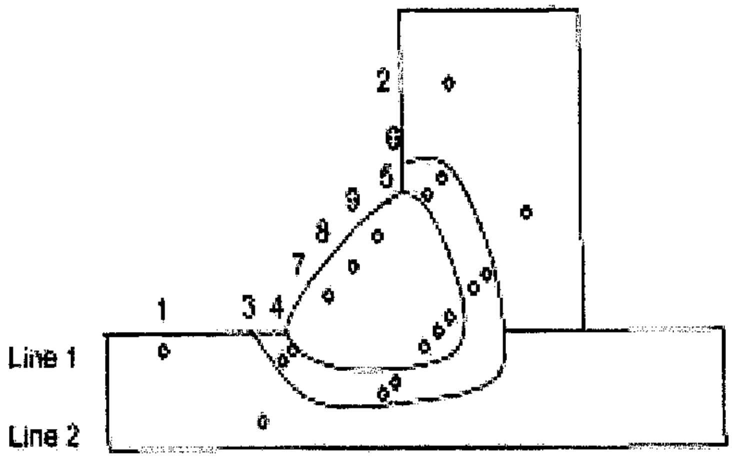
Procedure

- Square based pyramid
- Indenter pressed into specimen with a load of between 1 and 100kg for 15 seconds
- Length of diagonals measured using adjustable shutters and a built in microscope

Table 3.2 Form for vickers hardness test result

VICKERS HARDNESS TEST (HV 10)

Sketch



Indentor : Diamond Pyramid Angle 136

Load : 1kgf

Point	Location	Final Year Project	
		Line 1	Line 2
1 2	Base Metal		
3 4 5 6	HAZ		
7 8 9	Weld Metal		

b) Macro etch Test

Macro examination - Macro examinations were used to give a visual evaluation of a cross-section of a welded joint. It was carried out on full thickness specimens. The width of the specimen should include HAZ,

The test specimens were prepared (Please refer Appendix 1) with a finish suitable for macro-etch examination. A suitable solution (Nital) was used for etching to give clear definition of the weld

Acceptance Criteria for Macro-etch Test

For acceptable qualification, the test specimens, when inspected visually, were conformed to the following requirements:

- Fillet welds should have fusion to the root of the joint, but not necessarily beyond.
- Minimum leg size should meet the specified fillet weld size.
- The fillet welds should have the following:
    - no crack
    - through fusion between adjacent layers of weld metals and between weld metal and base metal.
    - Weld profile conforming to special detail, but with none of the variations prohibited.
- No undercut exceeding 1/32 in (1 mm)

Table 3.3 Form for macro etch examination result

Report No.:	**MACRO ETCH EXAMINATION**	
Test Result Interpretation:		

c) Micro examination (optical microscopy)

Images of the microstructure were obtained at appropriate levels of magnification (not necessarily the highest). It should be able to answer some of these questions:

- What phases are present in the microstructure?
- Are the phases consistent with what you expect from the phase diagram?
- What is the shape of each phase or grain structure?
- Are there any peculiar grains?
- Why do these strange shapes occur?

3.2 TOOLS AND EQUIPMENT

a) Shielded Metal Arc Welding Equipment

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.

b) Vickers Hardness Tester

The Vickers hardness test was developed as an alternative method to measure the hardness of materials.

c) Magnetic Particle Tester

Magnetic particle inspection processes are non-destructive methods for the detection of defects in ferrous materials.

d) Ultrasonic Tester

It is a very short ultrasonic pulses-waves with center frequencies ranging from 0.1-15 MHz and occasionally up to 50 MHz are launched into materials to detect internal flaws or to characterize materials.

e) Dye Penetrant

It also called liquid penetrant inspection (LPI), is a widely applied and low-cost inspection method used to locate surface-breaking defects in all non-porous materials (metals, plastics, or ceramics).

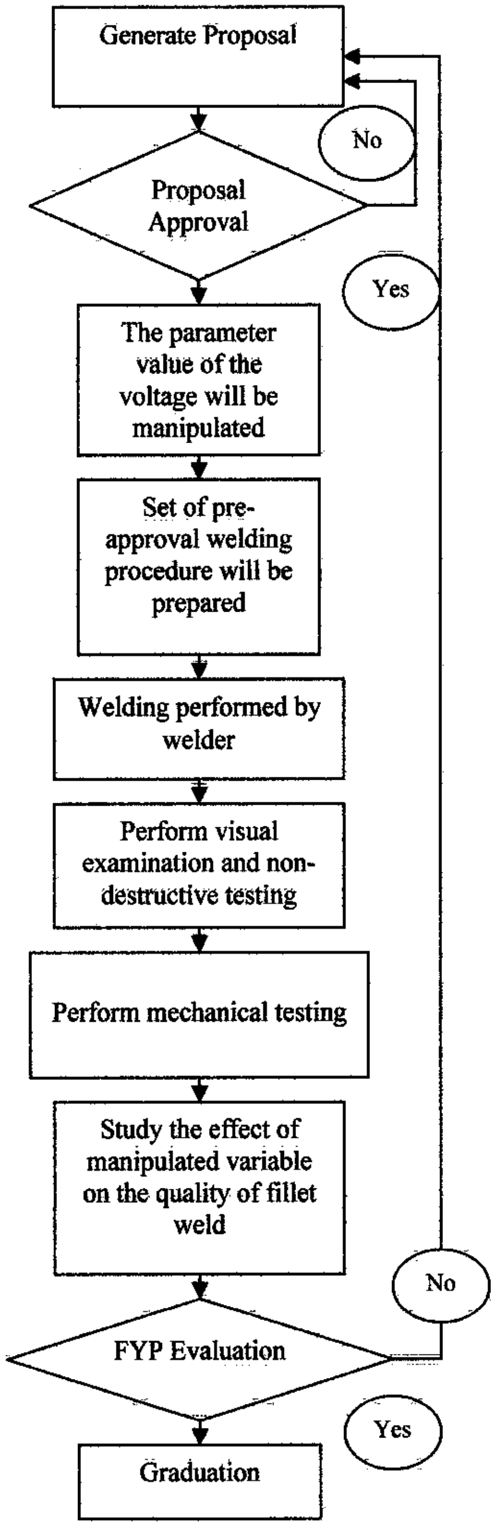
f) Abrasive cutter

To cut the samples.

h)Optical Microscopy

To obtain images of the microstructure at appropriate levels of magnification.

Flow Chart of Methodology



CHAPTER 4

RESULTS & DISCUSSIONS

4.1 RESULTS

4.1.1 Cutting the Steel

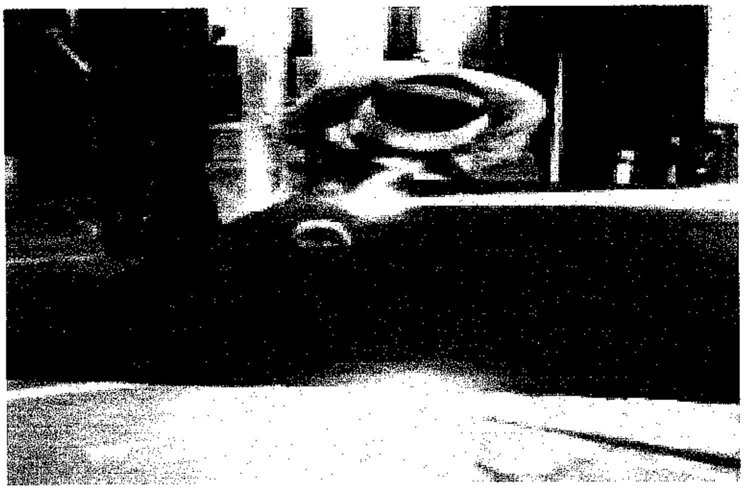


Figure 4.1 Cutting with plasma cutter

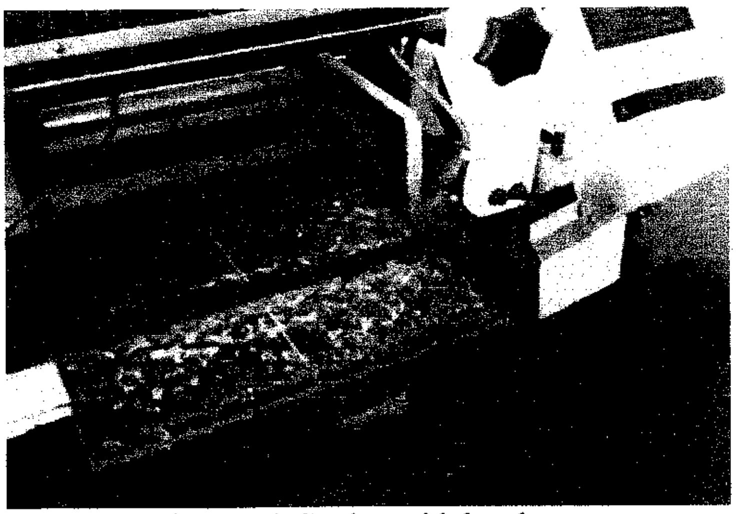


Figure 4.2 Cutting with band saw

4.1.2 Welding the Plate

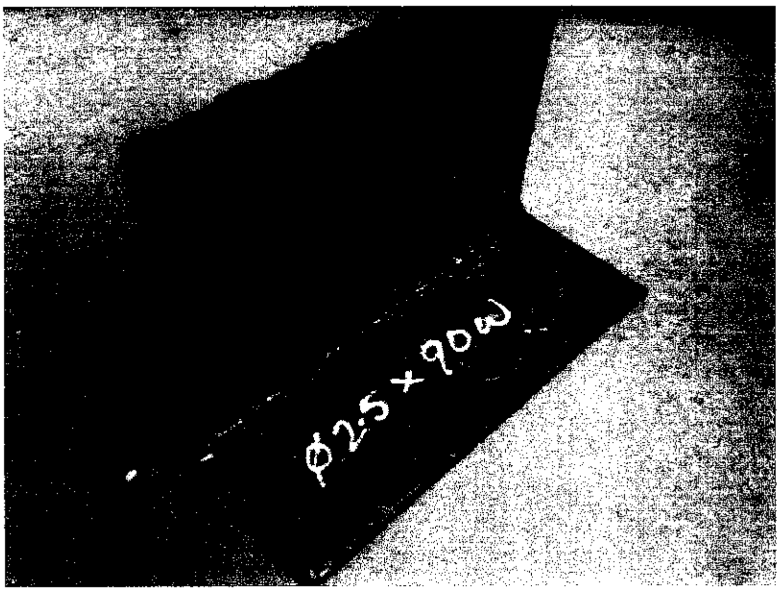


Figure 4.3 Welded plate with welding voltage, 90V (PLATE 1)

Figure 4.4 Welded plate with welding voltage, 120V (PLATE 2)

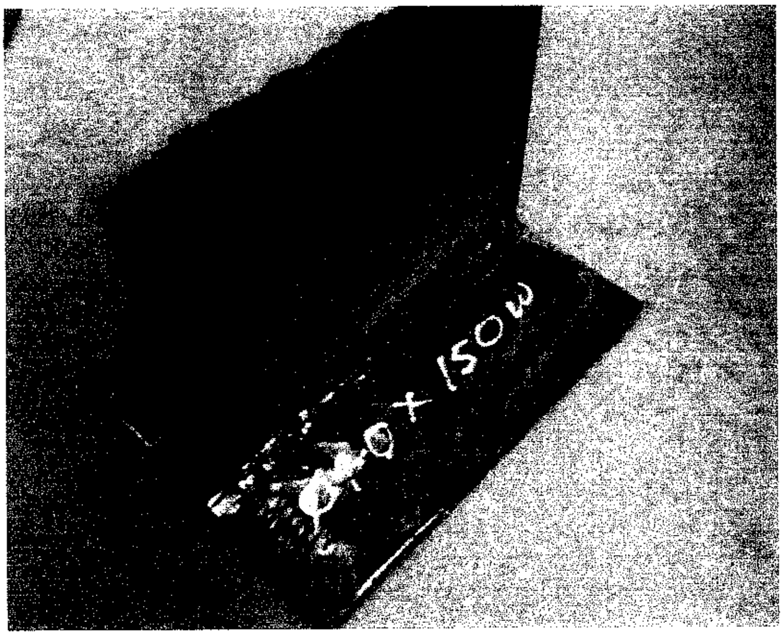
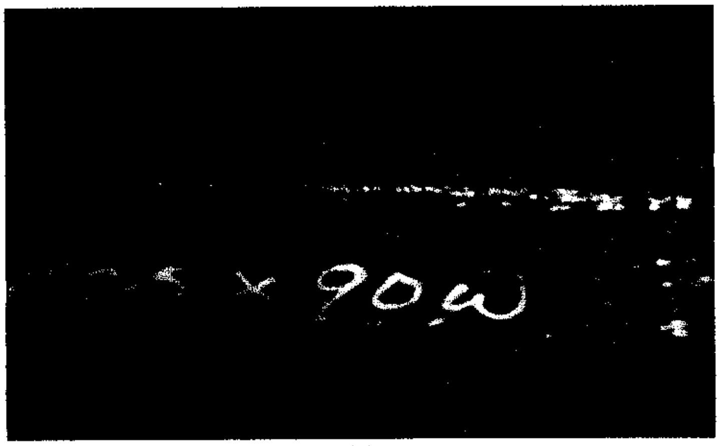


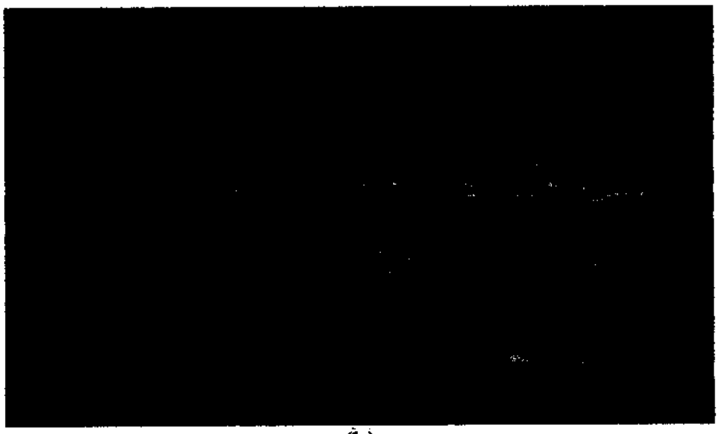
Figure 4.5 Welded plate with welding voltage, 150V (PLATE 3)

4.1.3 Visual Examination

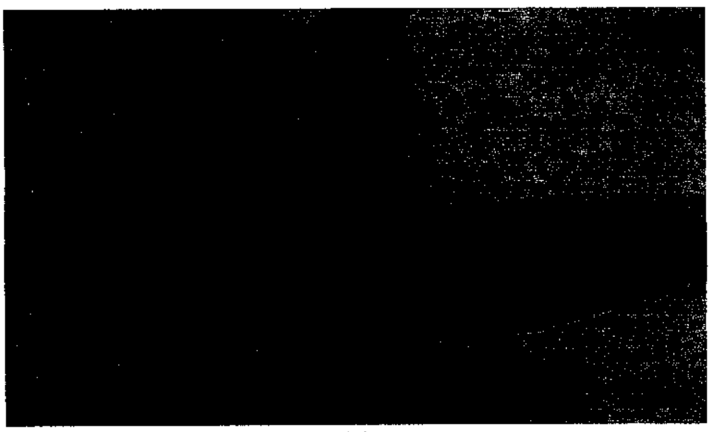
PLATE 1



(a)



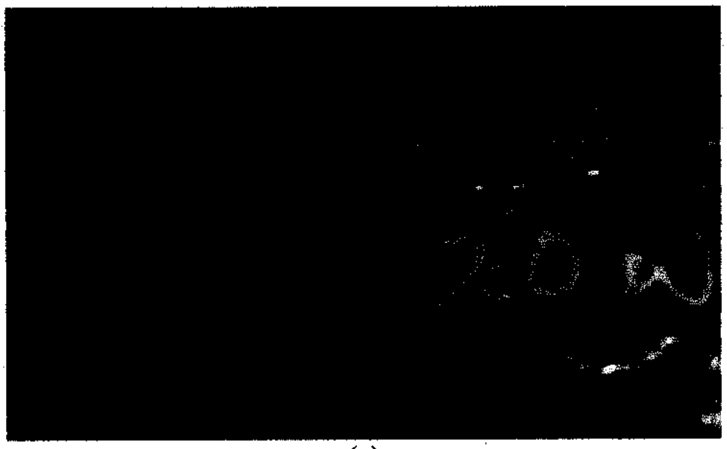
(b)



(c)

Figure 4.6 Visual examinations for PLATE 1

PLATE 2



(a)

(b)

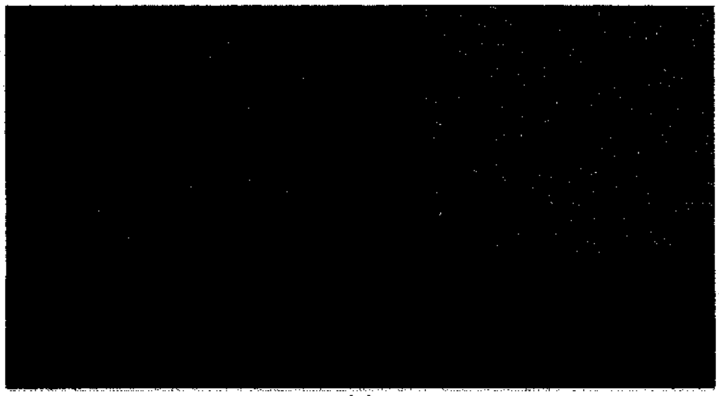
(c)

Figure 4.7 Visual examinations for PLATE 2

PLATE 3

(a)

(b)



(c)

Figure 4.8 Visual examinations for PLATE 3

4.1.4 Non-destructive Testing For Surface Crack Detection

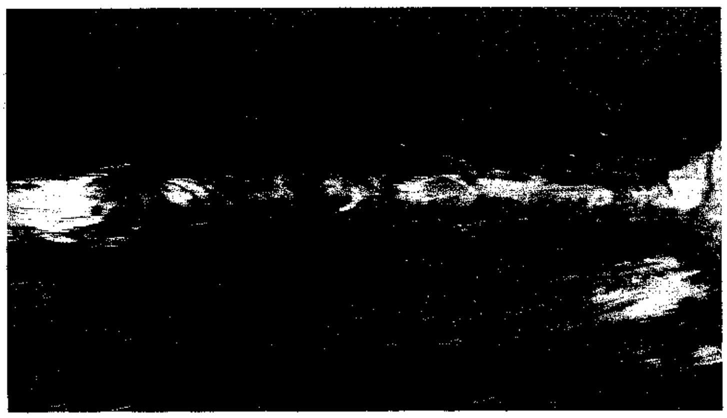
Dye Penetrant Test

Result

PLATE 1

(a)

(b)



(c)

Figure 4.9 Dye penetrant results for PLATE 1

PLATE 2

(a)

(b)

(c)

Figure 4.10 Dye penetrant results for PLATE 2

PLATE 3

(a)

(b)

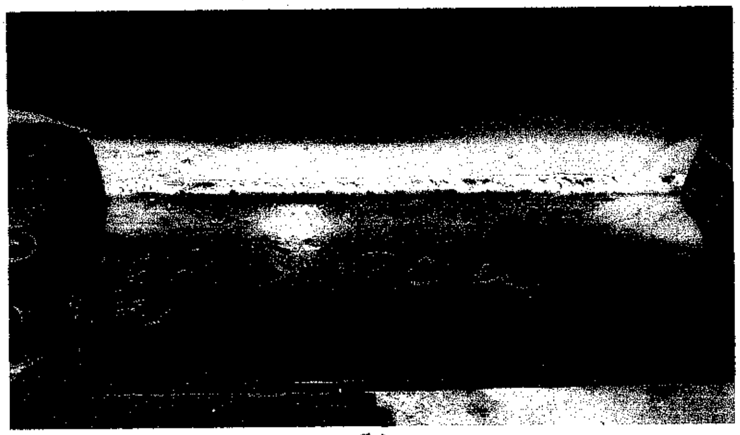
Figure 4.11 Dye penetrant results for PLATE 3

Magnetic Particle Testing

Black Magnetic Ink and Result

PLATE 1

(a)



(b)

(c)

Figure 4.12 Magnetic particle testing results for PLATE 1

PLATE 2

(a)

(b)

(c)

Figure 4.13 Magnetic particle testing results for PLATE 2

PLATE 3

(a)

(b)

Figure 4.14 Magnetic particle testing results for PLATE 3

PLATE 1

Table 4.1 Magnetic particles and dye penetrant test result for PLATE 1

<table>
<tr><th colspan="5">MAGNETIC PARTICLE AND DYE PENETRANT TEST</th></tr>
<tr><td colspan="3">Client:
Project:</td><td colspan="2">Inspection Date:
Location:
Specification:</td></tr>
<tr><td colspan="3">Material:
Welding Process:
Weld Prep.:</td><td colspan="2">Thickness:
Surface Condition:</td></tr>
<tr><td colspan="3">MAGNETIC PARTICLE INSPECTION</td><td colspan="2">DYE PENETRANT INSPECTION</td></tr>
<tr><td colspan="3">Base:
Media:
Equipment:
Magnetizing Current:</td><td colspan="2">Penetrant:
Remover:
Developer:</td></tr>
<tr><td>No.</td><td>Joint Reference</td><td>Interpretation</td><td>Result</td><td>Remark</td></tr>
<tr><td></td><td></td><td>No defect</td><td></td><td>No defect</td></tr>
<tr><td colspan="3">NDT Inspector:</td><td colspan="2">Approved by:
Client's Rep:</td></tr>
</table>

PLATE 2

Table 4.2 Magnetic particles and dye penetrant test result for PLATE 2

<table>
<tr><th colspan="5">MAGNETIC PARTICLE AND DYE PENETRANT TEST</th></tr>
<tr><td colspan="3">Client:
Project:</td><td colspan="2">Inspection Date:
Location:
Specification:</td></tr>
<tr><td colspan="3">Material:
Welding Process:
Weld Prep.:</td><td colspan="2">Thickness:
Surface Condition:</td></tr>
<tr><td colspan="3">MAGNETIC PARTICLE INSPECTION</td><td colspan="2">DYE PENETRANT INSPECTION</td></tr>
<tr><td colspan="3">Base:
Media:
Equipment:
Magnetizing Current:</td><td colspan="2">Penetrant:
Remover:
Developer:</td></tr>
<tr><td>No.</td><td>Joint Reference</td><td>Interpretation</td><td>Result</td><td>Remark</td></tr>
<tr><td></td><td></td><td>No defect</td><td></td><td>No defect</td></tr>
<tr><td colspan="3">NDT Inspector:</td><td colspan="2">Approved by:
Client's Rep:</td></tr>
</table>

PLATE 3

Table 4.3 Magnetic particles and dye penetrant test result for PLATE 3

<table>
<tr><th colspan="5">MAGNETIC PARTICLE AND DYE PENETRANT TEST</th></tr>
<tr><td colspan="3">Client:
Project:</td><td colspan="2">Inspection Date:
Location:
Specification:</td></tr>
<tr><td colspan="3">Material:
Welding Process:
Weld Prep.:</td><td colspan="2">Thickness:
Surface Condition:</td></tr>
<tr><td colspan="3">MAGNETIC PARTICLE INSPECTION</td><td colspan="2">DYE PENETRANT INSPECTION</td></tr>
<tr><td colspan="3">Base:
Media:
Equipment:
Magnetizing Current:</td><td colspan="2">Penetrant:
Remover:
Developer:</td></tr>
<tr><td>No.</td><td>Joint Reference</td><td>Interpretation</td><td>Result</td><td>Remark</td></tr>
<tr><td></td><td></td><td>No defect</td><td></td><td>No defect</td></tr>
<tr><td colspan="3">NDT Inspector:</td><td colspan="2">Approved by:
Client’s Rep:</td></tr>
</table>

Ultrasonic Testing

Figure 4.15 Oscilloscope of ultrasonic testing

PLATE 1

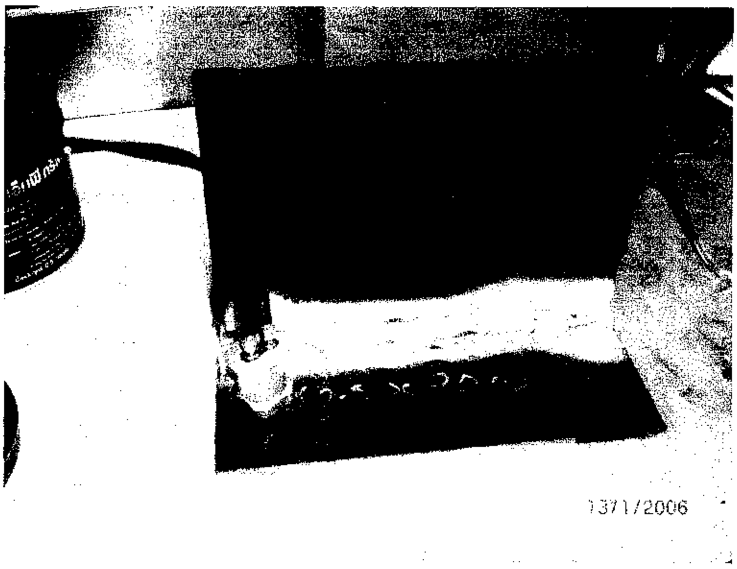


Figure 4.16 Ultrasonic testing for PLATE 1

PLATE 2

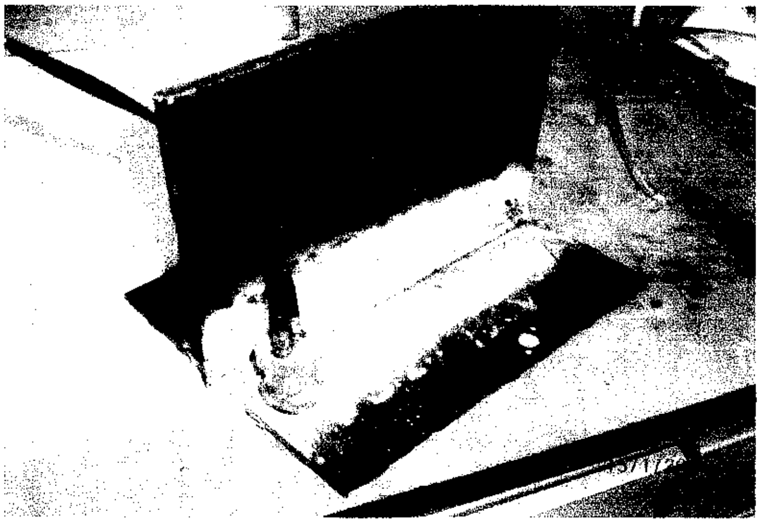


Figure 4.17 Ultrasonic testing for PLATE 2

PLATE 3

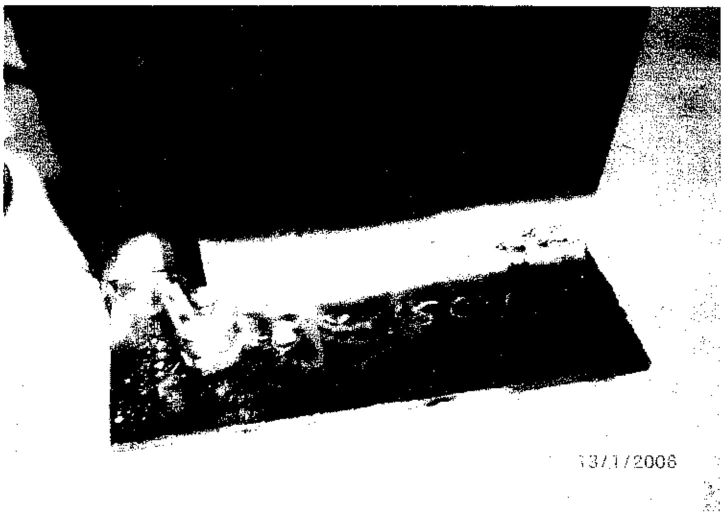


Figure 4.18 Ultrasonic testing for PLATE 3

4.1.5 Mechanical Testing

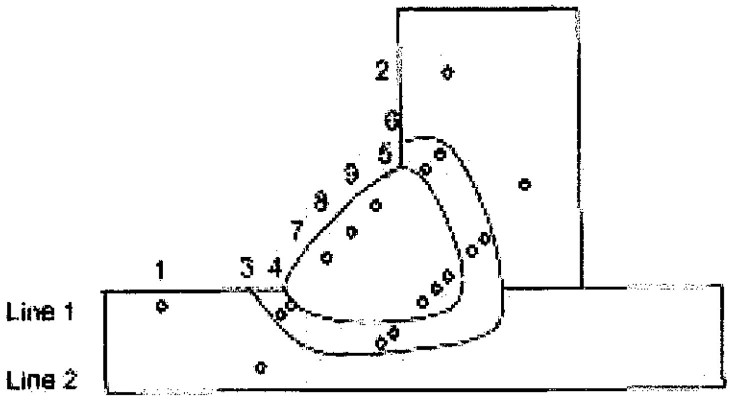
Vickers Hardness Testing

PLATE 1

Table 4.4 Vickers hardness test result for PLATE 1

VICKERS HARDNESS TEST (HV)

Sketch



Indentor : Diamond Pyramid Angle 136

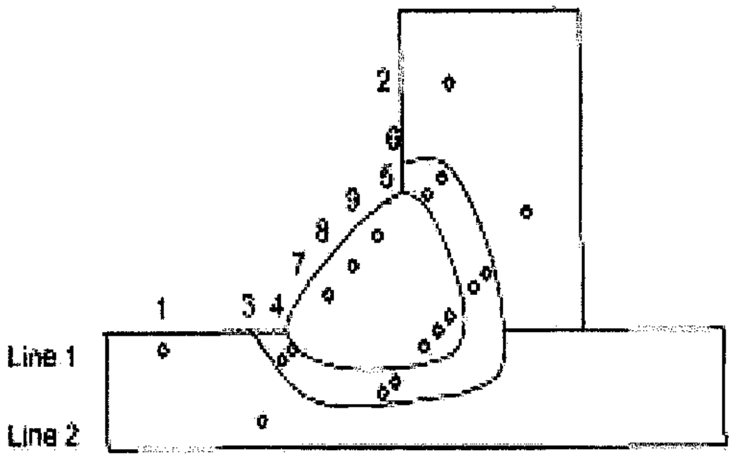
Load : 1kgf

Point	Location	Final Year Project	
		Line 1	Line 2
1	Base Metal	146.5	-
2		148.5	
3	HAZ	173.1	-
4		172.9	
5		171.0	
6		173.2	
7	Weld Metal	221.0	-
8		233.7	
9		229.5	

Table 4.5 Vickers hardness test result for PLATE 2

VICKERS HARDNESS TEST (HV)

Sketch



Indentor : Diamond Pyramid Angle 136

Load : 1kgf

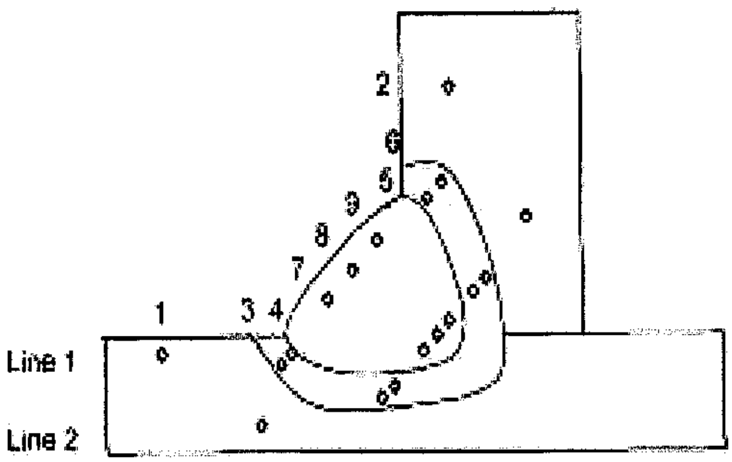
Point	Location	Final Year Project	
		Line 1	Line 2
1	Base Metal	142.1	-
2		141.5	
3	HAZ	154.2	-
4		153.9	
5		153.5	
6		154.1	
7	Weld Metal	191.7	-
8		194.7	
9		193.5	

PLATE 3

Table 4.6 Vickers hardness test result for PLATE 3

VICKERS HARDNESS TEST (HV)

Sketch



Indentor : Diamond Pyramid Angle 136

Load : 1kgf

Point	**Location**	**Final Year Project**	
		Line 1	**Line 2**
1	Base Metal	138.3	-
2		140.5	
3	HAZ	128.1	-
4		127.5	
5		126.9	
6		128.5	
7	Weld Metal	184.2	-
8		180.3	
9		181.5	

Macro etch Test

PLATE 1

Table 4.7 Macro etch examination result for PLATE 1

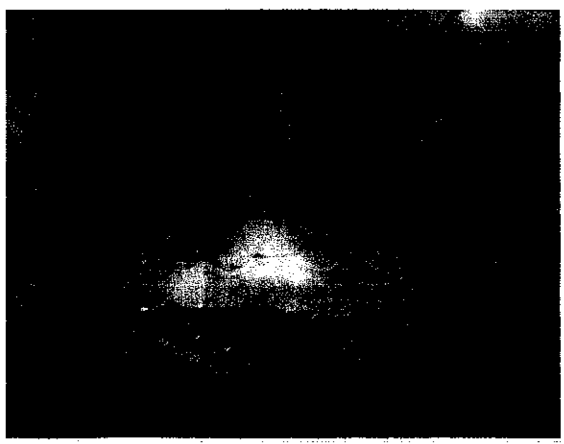
Report No.:	**MACRO ETCH EXAMINATION**	
Test Result  Interpretation: It conform the acceptance criteria		

PLATE 2

Table 4.8 Macro etch examination result for PLATE 2

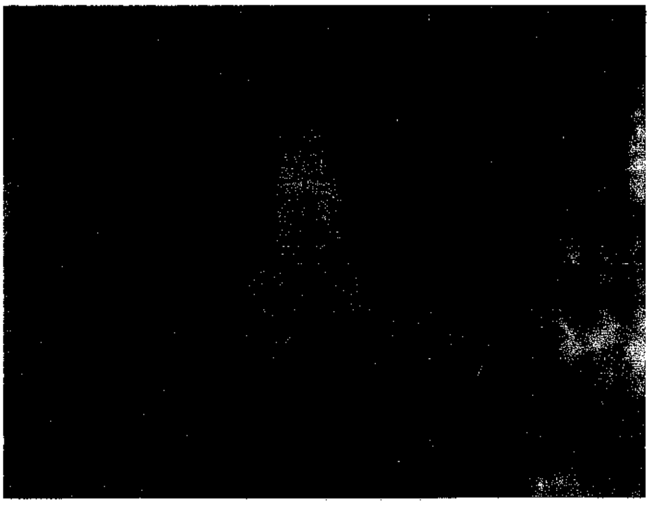
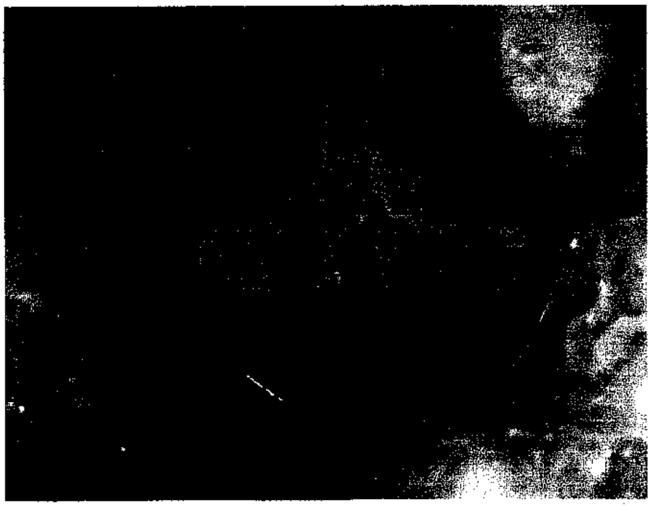
Report No.:	**MACRO ETCH EXAMINATION**	
Test Result  Interpretation: It conform the acceptance criteria		

PLATE 3

Table 4.9 Macro etch examination result for PLATE 3

<table>
<tr><td>Report No.:</td><td>MACRO ETCH
EXAMINATION</td><td></td></tr>
<tr><td colspan="3">Test Result

Interpretation: It conform the acceptance criteria</td></tr>
</table>

Micro examination (optical microscopy)

PLATE 1

Base Metal

Figure 4.19 Micro examinations result for base metal of PLATE 1

Weld Metal

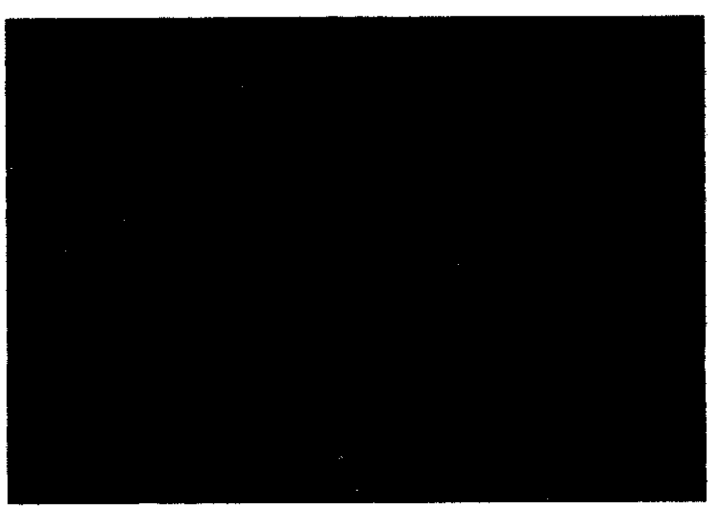


Figure 4.20 Micro examinations result for weld metal of PLATE 1

PLATE 2

Base Metal

Figure 4.21 Micro examinations result for base metal of PLATE 2

Weld Metal

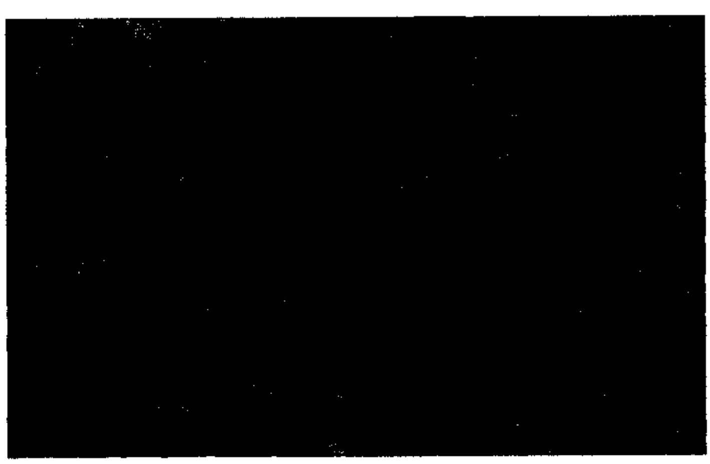


Figure 4.22 Micro examinations result for weld metal of PLATE 2

PLATE 3

Base Metal

Figure 4.23 Micro examinations result for base metal of PLATE 3

Weld Metal

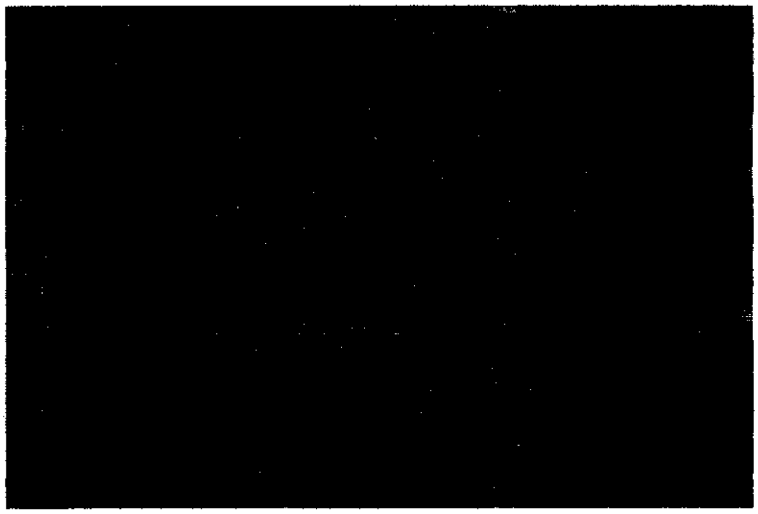


Figure 4.24 Micro examinations result for weld metal of PLATE 3

4.2 DISCUSSIONS

4.2.1 Visual Examination

By visual examination as in Figure 4.6-4.8, the plates were found to have the characteristics below:

- Free of cracks.
- Have all craters filled to the full cross-section of the weld.
- Have the face of the weld flush with the surface of the base metal.
- Undercut not exceed 1/32 inch (1 mm)
- Weld reinforcement shall exceed 1/8 inch (3mm)
- The roots of the weld have been inspected, and there are no evidence of cracks, incomplete fusion, or inadequate joint penetration. A concave root surface is permitted within the limits, provided the total thickness is equal to or greater than that of the base metal.
- Maximum root surface concavity is 1/16 inch (1.6 mm) and the maximum melt-through is 1/8 inch (3 mm).

4.2.2 Non-destructive Testing for surface crack detection

a) Dye penetrant inspection (DPI)

This technique as in Figure 4.9-4.11 was used to check the surface discontinuity. By using this technique, sub-surface discontinuity was not found.

b) Magnetic particle testing

This technique as in Figure 4.12-4.14 was used to check the sub-surface discontinuity. By using this technique, there was no sub-surface discontinuity that could be observed.

c) Ultrasonic testing

This technique as in Figure 4.15-4.18 was used to check the sub-surface discontinuity. By using this technique, no sub-surface discontinuity was found.

4.2.3 Mechanical testing

a) Vickers Hardness Testing

From the results as in Table 4.4-4.6, PLATE 1 has the highest hardness between the base metal and weld metal. The PLATE 3 has the lowest hardness between the base metal and weld metal. It shows that the PLATE 1 is the most brittle and less ductile. Whereas, for the PLATE 3, it shows that it is less brittle and has high ductility. Apart from that, it shows that the PLATE 1 has bigger residual stress than the other plates.

b) Macro etch Test

Macro etch test results as in Table 4.7-4.9 show the following characteristics:

- Fillet welds have fusion to the root of the joint, but not necessarily beyond.
- Minimum leg size meets the specified fillet weld size.
- The fillet welds have the following:
    - no crack
    - through fusion between adjacent layers of weld metals and between weld metal and base metal.
    - Weld profile conforming to special detail, but with none of the variations prohibited.
- No undercut exceeding 1/32 in (1 mm)

Furthermore, the PLATE 3 (150V) deeper fusion than the other plates. This is because it was exerted by more heat input, thus melt more base metals and weld metal.

c) Micro examination (optical microscopy)

Micro examination of Figure 4.19-4.24 show the microstructures of the weldment of PLATE 1, 2 and 3. No defects were found at these welding sections.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

Based on the results, the visual examination and non-destructive testing indicate that no significant effect on the applied voltages. The quality of weld is mainly affected by the welder itself and by using unsuitable setting for specified welding work. However, the mechanical testing shows the effect of different voltage on the welding. The higher voltage decreases the brittleness of the weld and increases its ductility. Therefore less residual stress could be found in the weld. Macro etch show that the higher voltage could produce the weld with deeper fusion.

5.2 RECOMMENDATIONS

Recommendations for future project work; in order to have better result, is to decrease the residual stress. Residual stress is one of the major problems to the weld. The residual stress is caused by localized heating and cooling during welding, the expansion and contraction of the weld area. The problem caused by residual stresses such as distortion, buckling and cracking can be reduced by preheating the base metal or the parts to be welded. Preheating reduces distortion by reducing the cooling rate and the level of thermal stress developed by lowering the elastic modulus. This technique also reduces shrinkage and possible cracking of the joint.

Other methods of stress relieving include peening, hammering or surface rolling of the weld bead area. These techniques induce compressive residual stresses, which in turn, lower or eliminate tensile residual stresses in the weld. For multilayer welds, the first and last layers should not be peened in order to protect them against possible peening damage.

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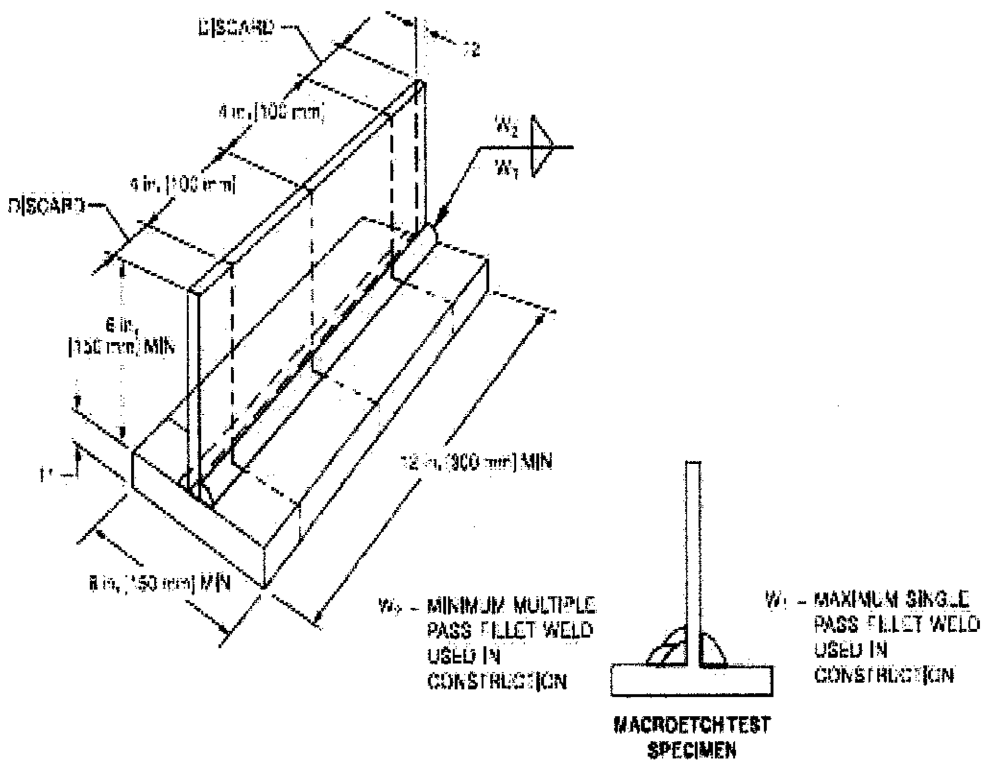
12. V. Gunaraj & N. Murugan, "Prediction of Heat Affected Zone Characteristics in Submerged Arc Welding of Structural Pipes", 29 November 2008 <http://files.aws.org/wj/supplement/Gunaraj2-02.pdf>

APPENDICES

Appendix 1



INCHES			MILLIMETERS		
Weld Size	T1 min	T2 min	Weld Size	T1 min	T2 min
3/16	1/2	3/16	5	12	5
1/4	3/4	1/4	6	20	6
5/16	1	5/16	8	25	8
3/8	1	3/8	10	25	10
1/2	1	1/2	12	25	12
5/8	1	5/8	16	25	16
3/4	1	3/4	20	25	20
> 3/4	1	1	> 20	25	25

General Note: Where the maximum plate thickness used in production is less than the value shown above, the maximum thickness of the production pieces may be substituted for T1 and T2.

Figure 4.19—Fillet Weld Soundness Tests for WPS Qualification (see 4.11.2)

Appendix 2

WELDING PROCEDURE SPECIFICATION (WPS) Yes ☒

EQUALIFIED ______ *QUALIFIED BY TESTING* ______
Or PROCEDURE QUALIFICATION RECORDS (PQR) Yes ☒

Company Name *UTP*
Welding Process(es) *SMAW*
Supporting PQR No.(s) *HLE-PQR-17-34*

Identification # ______
Revision ______ Date ______ By ______
Authorized by ______ Date ______
Type – Manual ☐ Semi-Automatic ☐
Machine ☒ Automatic ☐

JOINT DESIGN USED

Type ______
Single : ☒ Double Weld ☐
Backing : Yes ☒ No ☐

Backing Material: ______
Root Opening ______ Foot Face Dimension ______
Groove Angle ______ Radius (J-U) ______
Back Gouging : Yes ☐ No ☒ Method ______

POSITION

Position of Groove Fillet

Vertical Progression : ***Up*** ☐ ***Down*** ☐

ELECTRICAL CHARACTERISTICS

Transfer Mode (GMAW) Short-Circuiting ☐
Globular ☐ Spray ☐

Current: AC ☐ DCEP ☐ DCEN ☐
Pulsed ☐
Other ______
Tungsten Electrode (GTAW)

Size : ______
Type: ______

BASE METALS

Material Spec. *ASTM A36*
Type of Grade ______
Thickness: Groove ______ Fillet ______
Diameter (Pipe) ______

TECHNIQUE

Stringer or Weave Bead: ______
Multi-pass or Single Pass (per side) *SINGLE*
Number of Electrodes ______

FILLER METALS

AWS Specification ______
AWS Classification ______

Electrode Spacing
Longitudinal ______
Lateral
Angle ______
Contact Tube to Work Distance ______
Peening ______
Interpass Cleaning : ______

SHELDING

Flux ______ Gas ______
Composition ______
Electrode-Flux (Class) ______ Flow Rate ______
Gas Cup Size ______

POSTWELD HEAT TREATMENT

Temp. ______
Time ______

PREHEAT

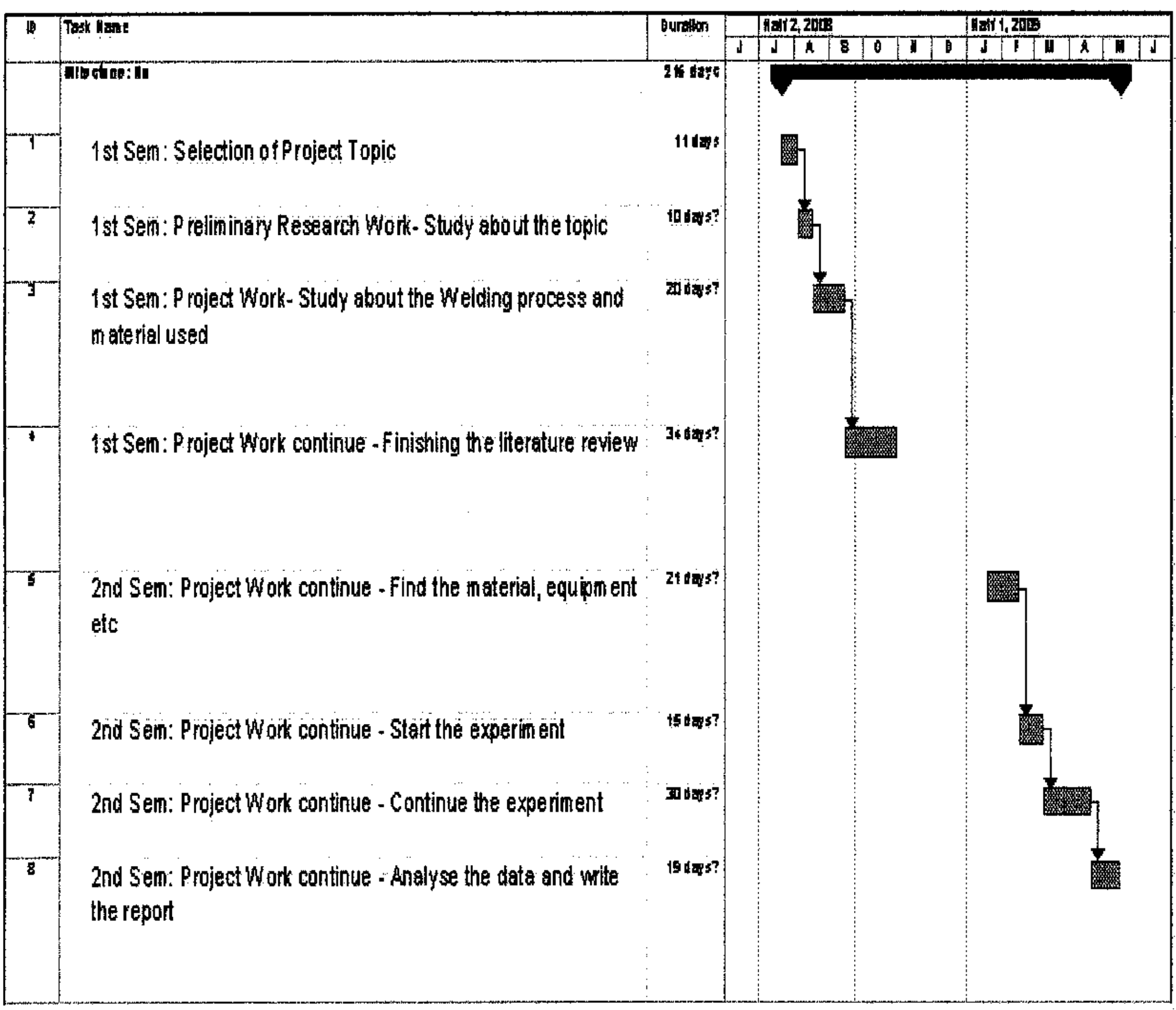
Preheat Temp., Min. ____________________

Interpass Temp., Min ______________ Max ________

WELDING PROCEDURE									
Pass or Weld Layer(s)	rocess	Filler Metals		Current		Volt	Travel Speed	Joint Details
		Class	Diam.	Type & Polarity	Amps or Wire Feed Speed			
1	*SMAW*	*E7018*	*2.5*	*DC+*	*100*	*90*	*83*	*FILLET*
1	*SMAW*	*E7018*	*3.2*	*DC+*	*100*	*120*	*83*	*FILLET*
1	*SMAW*	*E7018*	*4.0*	*DC+*	*100*	*150*	*83*	*FILLET*

Appendix 3

Gantt Chart



Appendix 4

Milestone

Milestone for the First Semester of 2-Semester Final Year Project

No.	Detail/ Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Selection of Project Topic		■													
2	Preliminary Research Work				■											
3	Submission of Preliminary Report				■											
4	Project Work							■								
5	Submission of Progress Report									■						
6	Seminar									■						
7	Project Work Continues															■
8	Submission of interim report															■
9	Oral Presentation															■

Milestone for the Second Semester of 2-Semester Final Year Project

No.	Detail/ Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Project Work Continue				■											
2	Submission of Progress Report 1				■											
3	Project Work Continue							■								
4	Submission of Progress Report 2									■						
5	Seminar									■						
6	Project Work Continue													■		
7	Poster Exhibition											■				
8	Submission of Dissertation													■		
9	Oral Presentation													■		