

DESIGN, FABRICATION AND TESTING OF A SEMI-AUTOMATIC WELDING  
FIXTURE FOR CIRCUMFERENTIAL JOINING CYLINDERS USING MIG  
WELDING

HUZAIMI BIN A. HAMID

UNIVERSITI TEKNOLOGI MALAYSIA

**DESIGN, FABRICATION AND TESTING OF A SEMI-AUTOMATIC  
WELDING FIXTURE FOR CIRCUMFERENTIAL JOINING CYLINDERS  
USING MIG WELDING**

**HUZAIMI BIN A. HAMID**

A project report submitted in partial fulfillment of the  
requirements for the award of the degree of  
Master of Mechanical Engineering (Advanced Manufacturing Technology)

Faculty of Mechanical Engineering  
Universiti Teknologi Malaysia

**MAY 2010**

To my believed “Allah s.w.t”  
And to my beloved mother and father

## ACKNOWLEDGEMENT

In preparing of this thesis, I was in dealing with a lot of people who are involved with fabrication, information gathering, advisory and problem solving including the academicians and practitioners. They have given with a full strength to contribute towards of my understanding and thoughts. I wish to express my appreciation to my main supervisor, Prof.Madya Zainal Abidin Ahmad for encouragement, guidance, advised and friendship. I am also a very thankful to my Co-Supervisor En. Mohzani Mokhtar, lecturer of Pusat Pengajian Kejuruteraan Mekanikal, Kampus Kejuruteraan, Universiti Sains Malaysia (USM), for his guidance and being helpful to give an advised, motivation, suggestion and guidance. Hopefully that Allah s.w.t will give them a better of life as present and on future.

I am also indebted to Universiti Teknologi Malaysia (UTM) for funding my Master study on information access either direct or indirect contact, to the Librarians of Universiti Sains Malaysia (USM) also deserve special thanks for their assistance and support in supplying the relevant material and literatures.

To my colleagues and other Master students should also be recognized by their support that provided the knowledge and practical at various occasions. Unfortunately, it is not possible to list all of them in this limited space. I am grateful to all my family members for supporting, motivating and helping to achieve this opportunity.

## ABSTRACT

This paper presents the systematic approach of design, fabrication and testing of the circumferentially joining on welding fixture which is being carried out at Kolej Kemahiran Tinggi MARA Balik Pulau (welding fabrication) and PPKM, Kampus Kejuruteraan USM Nibong Tebal, Pulau Pinang (destructive testing). The MIG welding unit is used to make a circumferential joining on tank and piping which are fixed onto the welding fixture and a several parameters setting of voltage, current and travel speed (rotational speed) is used for fabrication setup. The ASME (American Society of Mechanical Engineers) Code VIII (Pressure Vessels and Piping) is applied based on circumferential welding methodology standard. The research are focused to the structure produce by emphasis on the mild steel (0.16 – 0.29% carbon) as the common tank and piping materials. The fabrication fixture with constant speed of rotation by revolved the tank or pipe is developed as a dynamic structure with electrical adjustable speed control motor. The joint of mechanical properties are determined by means of static tensile test, impact test and hardness test. The correlation between the welding joint and destructive testing is evaluated of its welding joint structure by using microscope.

## ABSTRAK

Kertas kajian ini menggunakan pendekatan sistematik terhadap rekabentuk, fabrikasi and ujian terhadap penyambungan secara lilitan pada perkakasan kimpalan yang mana dilaksanakan di Kolej Kemahiran Tinggi Mara Balik Pulau (untuk fabrikasi kimpalan) dan di PPKM, Kampus Kejuruteraan, Universiti Sains Malaysia, Pulau Pinang (untuk ujian dan analisa). Unit kimpalan MIG digunakan untuk menghasilkan kimpalan lilitan pada tangki dan paip yang mana dipasang diatas perkakasan kimpalan dan beberapa pelarasan parameter terhadap voltan, arus dan kelajuan gerakan (kelajuan putaran) digunakan sebagai penetapan fabrikasi. Piawaian ASME (American Society of Mechanical Engineers) Kod VIII (Kebuk Tekanan dan Pemaipan) digunakan berdasarkan kaedah piawaian kimpalan lilitan. Kajian ini memfokuskan terhadap struktur yang dihasilkan menggunakan keluli lembut (0.16 – 0.29% karbon) sebagai bahan asas tangki dan paip. Peralatan yang difabrikasi, mempunyai kelajuan putaran yang seragam dengan memutarakan tangki atau paip, yang menghasilkan struktur dinamik melalui pelarasan pada motor jenis kawalan kelajuan. Penyambungan terhadap sifat-sifat mekanikal ini ditentukan menggunakan ujian penegangan statik, ujian hentaman dan juga ujian kekerasan. Perhubungan diantara penyambungan kimpalan dan ujian destruktif ini dinilai dari segi struktur kimpalan oleh sambungannya menggunakan mikroskop.

## TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	<b>DECLARATION</b>	ii
	<b>DEDICATION</b>	iii
	<b>ACKNOWLEDGEMENT</b>	iv
	<b>ABSTRACT</b>	v
	<b>ABSTRAK</b>	vi
	<b>TABLE OF CONTENTS</b>	vii
	<b>LIST OF TABLES</b>	xi
	<b>LIST OF FIGURES</b>	xiii
	<b>LIST OF SYMBOLS</b>	xvi
	<b>LIST OF APPENDIX</b>	xvii
<b>1</b>	<b>INTRODUCTION</b>	
	1.1 Introduction	1
	1.2 Objective	3
	1.3 Scope of project	4
	1.4 Problem statement	4
<b>2</b>	<b>LITERATURE REVIEW</b>	
	2.1 Introduction	5
	2.2 Introduction to MIG (Metal Inert Gas) Welding	5
	2.3 Introduction of welding on tank and piping	7

2.4	Overview the previous researches related to circumferential joint welding	9
2.5	Overview the previous researches related on cylindrical shape fabrications	11
<b>3</b>	<b>DESIGN AND DEVELOPMENT OF WELDING FIXTURE</b>	
3.1	Introduction	14
3.2	Method of welding fixture fabrication	16
3.3	Conceptual design and sketching	
3.3.1	Sketching the concept	17
3.3.2	Pattern search	22
3.3.3	List of needs	24
3.3.4	List of metric	25
3.3.5	Needs-metrics matrix	26
3.3.6	Concept screening	27
3.3.7	Concept scoring	28
3.3.8	Final specifications	29
3.4	Project design	
3.4.1	Part description and selection	30
3.4.2	Determination of workpiece rotation system	40
3.5	Project fabrication	46
3.6	Project controlling system	
3.6.1	Working operation of pneumatic triggering system	49
3.6.2	Working operation of electrical circuit for rotation system	50
3.7	Bill of materials (BOM)	51
3.8	Project costing	
3.8.1	Design cost	60
3.8.2	Fabrication cost	61



<b>4</b>	<b>METHODOLOGY</b>	
4.1	Experimental preparation	66
4.2	Material specification	70
4.3	Welding parameters	
4.3.1	Welding voltages (V)	71
4.3.2	Welding current (Amp)	73
4.3.3	Travel speed	73
4.4	Testing and analysis	
4.4.1	Tensile test	75
4.4.2	Hardness test	78
4.4.3	Impact test	81
4.4.4	Welding structure	83
4.5	ASME standard and application	
4.5.1	ASME codes and application	84
4.5.2	ASME certification	86
<b>5</b>	<b>RESULT AND DISCUSSION</b>	
5.1	Introduction	88
5.2	Destructive test	89
5.3	Result of testing	
5.3.1	Criteria of welding joint by voltage regulation	90
5.3.2	Criteria of welding joint by travel speed regulation	92
5.3.3	Result of tensile test	93
5.3.4	Result of impact test	143
5.3.5	Result of hardness test	145
5.3.6	Welding structure	147
5.4	Discussion	152
5.5	Conclusion	152

<b>6</b>	<b>CONCLUSION</b>	
6.1	Introduction	153
6.2	Conclusion	153
6.3	Recommendation	154
	<b>REFERENCES</b>	156
	<b>APPENDIX A</b>	161
	<b>APPENDIX B</b>	164
	<b>APPENDIX C</b>	183
	<b>APPENDIX D</b>	189
	<b>APPENDIX E</b>	202

**LIST OF TABLES**

<b>TABLE NO.</b>	<b>TITLE</b>	<b>PAGE</b>
3.1	List of available needs	24
3.2	List of metric	25
3.3	Needs-metrics matrix	26
3.4	Concept screening	27
3.5	Concept scoring	28
3.6	Project final specification	29
3.7	Description of rotational shaft	30
3.8	Description of attachment roller	30
3.9	Description of bearing housing	31
3.10	Description of drive pulley	31
3.11	Description of driven pulley	32
3.12	Description of motor support plate	32
3.13	Description of stabilizer wheel plate	33
3.14	Description of stabilizer wheel shaft	33
3.15	Description of welding gun arm	34
3.16	Description of welding gun holder	34
3.17	Description of welding gun clamp 1	35
3.18	Description of welding gun clamp 2	35
3.19	Description of earth channel connector	36
3.20	Description of aluminium frame	36
3.21	Description of dark acrylic transparent	37

3.22	Description of control box	37
3.23	Description of stabilizer wheel holder	38
3.24	Description of cabinet	38
3.25	Motor speed selector without load	42
3.26	Motor speed selector with load	42
3.27	BOM for custom made parts	52
3.28	BOM for standard parts	55
3.29	Estimation of design cost	60
3.30	Estimation of fabrication cost	61
4.1	Workpiece material characteristic	70
4.2	Rockwell hardness scale	79
4.3	Standard guidelines of ASME applications chart	87
5.1	Setup by regulation of voltage	90
5.2	Setup by regulation of travel speed	92
5.3	Tensile test description for workpiece $\phi 74\text{mm}$	93
5.4	Simplification of tensile test for workpiece $\phi 74\text{mm}$	105
5.5	Tensile test description setup for workpiece $\phi 88\text{mm}$	106
5.6	Simplification of tensile test for workpiece $\phi 88\text{mm}$	118
5.7	Tensile test description setup for workpiece $\phi 101\text{mm}$	119
5.8	Simplification of tensile test for workpiece $\phi 101\text{mm}$	131
5.9	Tensile test description setup for workpiece $\phi 114\text{mm}$	132
5.10	Simplification of tensile test for workpiece $\phi 114\text{mm}$	142
5.11	Speed selector for all specimen ( $\phi 114\text{mm}$ )	143
5.12	Result of impact energy on the workpiece	144
5.13	Description of Hardness Test	145
5.14	Measurement of hardness by XY axis	146

## LIST OF FIGURES

<b>FIGURE NO.</b>	<b>TITLE</b>	<b>PAGE</b>
1.1	General common tank and piping (Tank Wikipedia, Free Encyclopedia)	1
1.2	Longitudinal and circumferential joints of tank (Pressure Vessel, Wikipedia, Free Encyclopedia)	2
2.1	General MIG welding system structure (Sacks & Bohnart, 2005)	6
2.2	Circumferential welding on tanks or pipe (Martha A. Baker, 1995)	8
3.1	Flow chart of Project Fabrication Process	15
3.2	Concept classification tree for tank and piping fabrication fixture	16
3.3	Concept 1	18
3.4	Concept 2	19
3.5	Concept 3	20
3.6	Concept 4	21
3.7	Apparatus for obtaining a butting contact of hollow tank courses to be circumferentially welded	22
3.8	Apparatus of forming circumferential welding	22
3.9	Method of welding tanks	23
3.10	Total assembly of finish parts	39
3.11	Workpiece rotational system	40

3.12	Rotating system	41
3.13	Formation of speed control motor without load	43
3.14	Formation of speed control motor with load (4.15kg)	43
3.15	Flow chart of welding apparatus fabrication	47
3.16	Steps of assembly for welding apparatus	48
3.17	Pneumatic circuit for triggering system	49
3.18	Electrical circuit for rotating system	50
3.19	Physical views of welding fixture	51
4.1	Setup workpiece to the fixture	67
4.2	Setup the nozzle to correct position with the workpiece	67
4.3	Start-up to rotate the workpiece and welding process	68
4.4	Simplification view the steps of circumferential welding processes on welding apparatus	69
4.5	Comparison strength between the carbon contain on mild steel	70
4.6	Voltage regulator on MIG welding unit (Miller Migmatic)	71
4.7	Determination of proper setting on voltage	72
4.8	Determination of proper setting on travel speed	74
4.9	Tensile Strength Tester	75
4.10	Workpiece shape for testing and analysis	76
4.11	Workpiece preparation and result by tensile test	77
4.12	Rockwell Hardness Tester	78
4.13	Workpiece position on Rockwell Hardness Tester	79
4.14	Workpiece preparation and result by hardness test	80
4.15	Izod Impact Tester schematic view	81
4.16	Strike of impact energy on workpiece	82
4.17	Workpiece setup on impact tester	82
4.18	Welding joint structure on specimen	83
4.19	Layout certification test	86

5.1	Welding by circumferential joint on cylindrical shape	89
5.2	Result on workpiece by regulation of voltage	90
5.3	Result on workpiece by regulation of travel speed	92
5.4	Graph Load vs Displacement for workpiece ( $\phi 74\text{mm}$ )	104
5.5	Graph Stress vs Strain for workpiece ( $\phi 74\text{mm}$ )	104
5.6	Graph Load vs Displacement for workpiece ( $\phi 88\text{mm}$ )	117
5.7	Graph Stress vs Strain for workpiece ( $\phi 88\text{mm}$ )	117
5.8	Graph Load vs Displacement for workpiece ( $\phi 101\text{mm}$ )	130
5.9	Graph Stress vs Strain for workpiece ( $\phi 101\text{mm}$ )	130
5.10	Graph Load vs Displacement for workpiece ( $\phi 114\text{mm}$ )	141
5.11	Graph Stress vs Strain for workpiece ( $\phi 114\text{mm}$ )	142
5.12	Axis being measured by Hardness tester	146
5.13	Structure view (specimen 1, $\phi 114\text{mm}$ ) before etching under 50x lens	148
5.14	Size of welding structure for specimen 1	149
5.15	Welding structure for specimen 1 under 50X lens	149
5.16	Size of welding structure for specimen 2	150
5.17	Welding structure for specimen 2 under 50X lens	150
5.18	Size of welding structure for specimen 3	151
5.19	Welding structure for specimen 3 under 50X lens	151

**LIST OF SYMBOLS**

<i>H</i>	-	Height
<i>W</i>	-	Width
<i>L</i>	-	Long
<i>Amp</i>	-	Ampere (Current)
$\phi$	-	Diameter
<i>V</i>	-	Voltage
<i>L</i>	-	Liter
<i>T</i>	-	Thickness
<i>N</i>	-	Rotational velocity
$\pi$	-	Phi = 3.142
<i>K</i>	-	Relay
<i>CW</i>	-	Clockwise
<i>CCW</i>	-	Counter-clockwise
<i>ASME</i>	-	American Society of Mechanical Engineering



## LIST OF APPENDIX

<b>APPENDIX</b>	<b>TITLE</b>	<b>PAGE</b>
A1	Project Gantt chart (Session I and Session II)	161
A2	Project schedule and project cost (custom made)	163
B1	Drawing : Rotational shaft	164
B2	Drawing: Attachment roller	165
B3	Drawing: Bearing housing	166
B4	Drawing: Drive pulley	167
B5	Drawing: Driven pulley	168
B6	Drawing: Motor support plate	169
B7	Drawing: Stabilizer wheel plate	170
B8	Drawing: Stabilizer wheel shaft	171
B9	Drawing: Welding gun arm	172
B10	Drawing: Welding gun holder	173
B11	Drawing: Welding gun clamp 1	174
B12	Drawing: Welding gun clamp 2	175
B13	Drawing: Earth channel connector	176
B14	Drawing: Aluminium frame	177
B15	Drawing: Dark acrylic transparent plate	178
B16	Drawing: Control box	179
B17	Drawing: Stabilizer wheel holder	180
B18	Drawing: Cabinet	181
B19	Drawing: Finish assembly	182

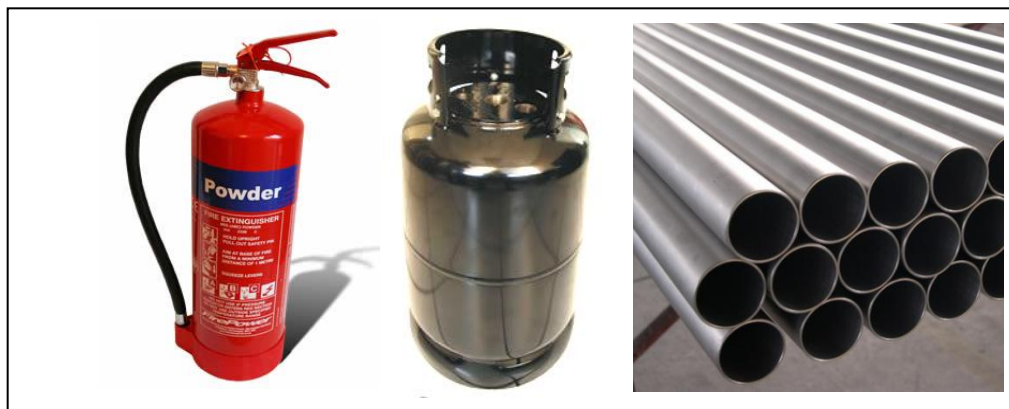
C1	Quotation: Aluminium profile frame	183
C2	Quotation: Electrical parts and common parts	184
C3	Quotation: Speed control motor	186
C4	Quotation: Pneumatic cylinder	187
C5	Quotation: Pneumatic multiple parts	188
D1	MIG welding catalogue	189
D2	Low carbon steel specification chart catalogue	200
E1	Piping Construction, A guide of owners, architect and engineers	202
E2	Welder certification test-pipe	206

## CHAPTER 1

### INTRODUCTION

#### 1.1 Introduction

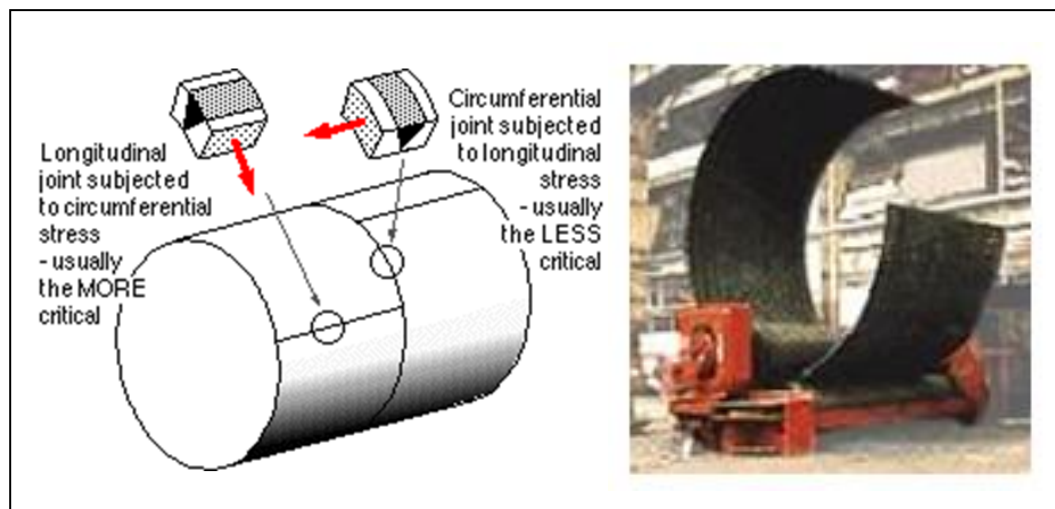
A common tank and piping is a product with the cylindrical shape designed to hold gases or liquids at pressure substantially different from the ambient pressure. The pressure differential is potentially dangerous and many fatal accidents have occurred in the history of their development and operation. Consequently, their design, manufacture and operation are regulated by engineering authorities backed up by laws. Generally, almost any material with good tensile properties that is chemically stable in the chosen application can be employed (Pressure vessels, Encyclopedia).



**Figure 1.1** General common tanks and piping (Tanks, Encyclopedia)

Many tanks and piping are made by steel. To manufacture a spherical tank as an example, forged parts would have to be welded together. Some mechanical properties of steel are increased by forging, but welding sometimes reduces these desirable properties. In case of welding, in order to make the tank meet international safety standard, the selecting of fabrication standard is being used (Martha A. Baker, 1995).

To apply a welding process for common tank fabrication, the cylinders of the tank are usually made from flat plates which are rolled and then welded along longitudinal joints. In the other hand, circumferential joints are used to attach end closures to the cylinder, and to weld together rolled plates for along the tank if plate size availability or rolling machine capacity is restricted. Weld types are usually different for longitudinal and circumferential joints, and therefore the joint stresses in a tank must satisfy the requirements (Larry Horath, 2001).



**Figure 1.2** Longitudinal and circumferential joints of tank (Pressure Vessel, Encyclopedia)

The circumferential joint of the cylindrical shape are being controlled as it fixed on the fixture for constant speed of rotation. The output of joining is a pair of workpiece with same thickness and diameter.

The general welding parameters in fabrication of tanks and piping are usually depends on weld techniques which consist voltage, current (ampere) and travel

speed(mm/min). More specifically, the welding equipment using the Metal Inert Gas (MIG) will consider also the wire speed feed factors. The performance of wire feed system can be crucial to the stability and reproducibility of MIG welding.

For the welding voltages or arc voltages, is determined by the distance between the tip of the electrode and the workpiece. In the constant voltage system, the welding voltage is controlled by the arc length held by the welder and the voltage sensing wire feeder. To sure the constant speed of welding, the support jig is being developed. The other parameters called welding current has the great effect on the deposition rate, the weld bead size and shape, and the penetration of the weld (Martha A. Baker, 1995)

The standard of designed and fabrication of the tank and piping are accordance with the ASME Code Section VIII. The specific requirements apply to several classes of material used in pressure vessel construction, and also fabrication methods such as welding, forging and brazing (J.Philip Ellenberger, P.E, 2004)

The present work is devoted towards establishing a model of constant welding fixture which created the outcome of workpieces by welding effect through the different parameters setting on the MIG welding unit. The investigation on the tensile strength, hardness and impact test while viewing the structure under the microscope will be carried out.

## **1.2 Objective**

The main objective of this project is to design, fabricate and test a welding fixture for welding the cylinder circumferentially using MIG process. A specified welding standard and procedures was used to evaluate the welding quality.

### 1.3 Scope of project

The scope of work is clearly define the specific field of the research and ensure that the entire content of this thesis is confined the scope. It will be:

- i. The MIG Welding set (Miller Migmatic<sup>®</sup>383) will be employed.
- ii. Mild steel will be used as the workpiece material.
- iii. The common tank and piping which has a cylindrical shape will be used.
- iv. The specified welding standard and procedure will be applied.
- v. A welding quality will be evaluated based on the destructive testing to the workpiece. (Tensile test, impact test and hardness test)

### 1.4 Problem statement

The evaluation to determine the exact parameters used on Metal Inert Gas (MIG) welding system for tank and piping fabrication with steel material is a necessary requirements to promote the proper circumferential joint. How does the setting of voltage, current and travel speed causes the good joint in a subjected of circumferential site of tanks and piping. The questions work out with:

- i. What are the relevant parameters should be used to determine the good of welding bead and welding width?
- ii. What is the best method to use to sure the concentration of welding would be done?
- iii. What type of fixture should be use to get the constantly welding process?
- iv. What are the best evaluations to use to determine the result of welding based on parameters setting?