



UNIVERSITI TEKNIKAL MALAYSIA MELAKA

**INVESTIGATION ON MICROSTRUCTURE BEHAVIOR AND HAZ
HARDNESS OF STAINLEES STEEL AISI304 AT DIFFERENT
FILLER WIRE DIAMETER AND VOLATGE USING MIG
WELDING**

Thesis submitted in accordance with the partial requirements of the Universiti
Teknikal Malaysia Melaka for the Bachelor of Manufacturing Engineering
(Manufacturing Process) with Honors

By

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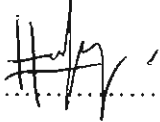
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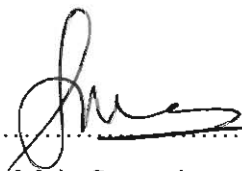
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ABSTRACT

The research work conducted in this dissertation aims to investigate the microstructure behavior and analyze Heat Affected Zone (HAZ) of austenitic stainless steel AISI 304 weldments. Here, the welding is conducted based on three different sizes of filler wire (ER308L). The sizes are 0.8mm, 1.0mm, and 1.2mm respectively. The arc voltage used is 20V, 25V and 30V. The current flow for metal inert gas (MIG) welding is set to constant value 100A. Meanwhile the plate size for base material is 5mm. The experiment starts with preparing the specimen by welding process using MIG welding equipment. Then the specimens are divided into two groups to undergo HAZ hardness and microstructure observation. The behavior of AISI 304 microstructure is studied using Optical Microscope. Hardness of HAZ area is evaluated by Rockwell hardness test. The result is to find the relation of different filler diameter size wire with the austenitic stainless steel microstructure behavior. A change in microstructural content and its properties are studied.

ABSTRAK

Kajian ini dijalankan bertujuan untuk mengkaji perubahan bentuk mikrostruktur serta mengkaji kawasan pengaruhan haba (HAZ) pada kimpalan '*austenitic stainless steel*' AISI 304. Proses pengimpalan dijalankan berdasarkan tiga saiz yang berza-beza diameter logam penambah '*filler wire*' jenis ER308L. Saiz logam penambah yang digunakan adalah 0.8mm, 1.0mm dan 1.2mm serta voltan yang digunakan pula adalah 20V, 25V, dan 30V. Arus yang digunakan pula adalah kekal pada 100A. Tebal plat '*stainless steel*' yang digunakan adalah 5mm. Eksperimen dimulakan dengan memotong kepingan plat '*stainless steel*' dan mengimpalnya menggunakan mesin kimpalan MIG. Selepas itu, penyambungan plat tersebut dipotong untuk dianalisa kekerasan HAZ dan perubahan bentuk mikrostruktur. Perubahan bentuk mikrostruktur dikaji dan dilihat dengan menggunakan '*Optical Microscope*' manakala tahap kekerasan HAZ diuji menggunakan mesin '*Rockwell hardness test*'. Ujian ini dilakukan adalah untuk mengkaji hubungan antara saiz diameter '*filler wire*' dan voltan terhadap perubahan mikrostruktur AISI 304 serta tahap kekerasan HAZ. Perubahan rupa bentuk atau mikrostruktur dan kandungannya juga di kaji dalam eksperimen ini.

DEDICATION

Dedicated to my beloved father, En. Ahmad bin Selamat and my lovely mother, Pn. Allpiah bte Hj. Kasbi who are very concern, patient and supporting. Last but not least, to all my brothers, sisters and friends. The work and success will never be achieved without all of you.

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LIST OF ABBREVIATIONS

GMA	-	Gas Metal Arc
GMAW	-	Gas Metal Arc Welding
GTA	-	Gas Tungsten Arc
GTAW	-	Gas Tungsten Arc Welding
HAZ	-	Heat Affected Zone
MIG	-	Metal Inert Gas
AISI	-	American Iron Standard Institute
SEM	-	Scanning Electron Microscopy
TIG	-	Tungsten Inert Gas
AWS	-	American Welding Society
ASTM	-	American Society for Testing and Materials
HRD	-	Thin steel and medium case hardened steel and pearlitic malleable iron
DOE	-	Design of experiment
C	-	Carbon
Cu	-	Copper
Si	-	Silicon
S	-	Sulfur
P	-	Phosphorus
Fe	-	Ferrous
Mg	-	Magnesium
Mn	-	Manganese
Wt. %	-	Weight of percentages
Zn	-	Zinc
CC	-	Constant Current
CV	-	Constant Voltage
DC	-	Direct Current
°C	-	Celsius
V	-	Voltage
A	-	Amperage

CHAPTER 1

INTRODUCTION

1.1 Introduction to Welding

Manufacturing operations require joining process in a way that is considered as an important process to be applied in almost every operation or process that involves fabricating or products. While there are many methods for joining metals, welding is one of the most convenient and rapid methods available. The term welding refers to the process of joining metals by heating them to their melting temperature and causing the molten metal to flow together. LeMouse (2008) stated in welding the aim is to use a form of blow torch to weld together two or more pieces of metal. This works by melting down these points of the metal to a point where they become soft enough to be pushed together. This means that the actual fabric of the metal itself has been joined at these parts, rather than using an intermediary substance to glue them together, and as such the bond is far more powerful and reliable – which is obviously paramount for cars, planes, bridges and anything else required to bear heavy weights and strong forces without breaking.

According Klobcar et al., (2004) welding is a complex process in terms of control of temperature fields, strains, residual stresses, formation of cracks and their propagation, especially when considering welding of hard tooling. Extreme temperature transients in the welded material often cause significant residual stress. Welding has become a prevalent mechanical joining methodology in various industries because of its advantages over other joining methods including design flexibility, cost savings, overall weight reduction and structural performance enhancement (Song, 2003). Mainly, in order to gain an acceptable weldments outcome, Song et al., (2003) recommended approaches such

like welding type selection, controlling welding process parameters and modifying the structural configuration.

Meanwhile, Jeffus (2004) stated filler material is added when needed to form a completed weld in the joint. It is also important to note that the word material is used because today welds can be made from a growing list of material such as plastic, glass, and ceramics. In general, welding includes any process that causes material join through the attractive action of inter-atomic or inter-molecular forces as opposed to purely macroscopic or even microscopic mechanical interlocking forces (Messler, 2004).

1.1.1 Fusion Welding

The arc-welding processes are undoubtedly the most important fusion welding processes. Heat is used to melt metal to form a bridge between the parts to be joined so that on removal of the heat source and solidification, the parts are united. The heat to melt metal in the joint can be provided by a variety of heat sources such as an oxy-fuel gas flame, gas shielded arcs, flux-shielded arcs, electron or laser beams. Here, part of the joint in the work piece is metal which has been melted or fused (Houldcroft and John, 1989).

Fusion welding is a joining process that uses fusion of the base metal to make weld. Three major types of fusion welding processes are as follows (Kou, 2003):

- a) Gas welding.
- b) Arc welding.
- c) High-energy beam welding.

1.1.2 Gas Metal Arc Welding (GMAW)

Gas Metal Arc Welding (GMAW), by definition, is an arc welding process which produces the coalescence of metals by heating them with an arc between a continuously fed filler metal electrode and the work. The process uses shielding from an externally supplied gas to protect the molten weld pool. The application of GMAW generally requires DC+ (reverse) polarity to the electrode. In non-standard terminology, GMAW is commonly known as MIG (Metal Inert Gas) welding and it is less commonly known as MAG (Metal Active Gas) welding. In either case, the GMAW process lends itself to weld a wide range of both solid carbon steel and tubular metal-cored electrodes.

The alloy material range for GMAW includes: carbon steel, stainless steel, aluminum, magnesium, copper, nickel, silicon bronze and tubular metal-cored surfacing alloys. The GMAW process lends itself to semiautomatic, robotic automation and hard automation welding applications. Table below shows that Gas Metal Arc Welding (GMAW) welding process is applicable for all materials of all thickness ranges while on the other hand Gas Tungsten Arc Welding (GTAW) or welding process is suitable mostly on thinner work pieces.

Table 1.1: Overview of welding processes (Kou, 2003)

Material	Thickness ^a	SMAW	SAW	GMAW	FCAW	GTAW	PAW	ESW	OFW	EBW	LBW
Carbon steels	S	X	X	X		X			X	X	X
	I	X	X	X	X	X			X	X	X
	M	X	X	X	X				X	X	X
Low-alloy steels	S	X	X	X	X	X		X	X	X	X
	I	X	X	X	X	X			X	X	X
	M	X	X	X	X			X	X	X	X
Stainless steels	S	X	X	X	X	X	X		X	X	X
	I	X	X	X	X	X	X		X	X	X
	M	X	X	X	X	X	X		X	X	X
Cast iron	S	X	X	X	X						
	I	X	X	X	X				X		
	M	X	X	X	X				X		
Nickel and alloys	S	X	X	X	X	X	X		X	X	X
	I	X	X	X	X	X	X		X	X	X
	M	X	X	X	X	X	X		X	X	X
Aluminum and alloys	S	X		X		X	X	X		X	X
	I	X		X		X			X	X	X
	M	X		X		X			X	X	X

According to Table 1.1, the process codes are as follows: SMAW (Shielded Metal Arc Welding), SAW (Submerged Arc Welding), GMAW (Gas Metal Arc Welding), FCAW (Flux Cored Arc Welding), GTAW (Gas Tungsten Arc Welding), PAW (Plasma Arc Welding), ESW (Electro Slag Welding), OFW (Oxy Fuel-Gas Welding), EBW (Electro Beam Welding), LBW (Laser Beam Welding). While the abbreviations: S, sheet up to 3mm; I, intermediate, 3-6mm; M, medium, 6-19mm; T, thick, 19mm and above; X, recommended respectively.

1.1.3 Stainless Steel Weldments

Stainless steel is extensively used in variety of application where corrosion resistance is required in combination with good strength and toughness. From the various classes of stainless steel, austenitic, martensitic, ferritic, precipitation-hardenable and duplex stainless steel, austenitic is the most easily welded. It contains 16-25% Cr, 7-20% Ni, and less than 0.08% C (Shankar, 2006). Jeffus (2004) stated that keeping the carbon content low in stainless steel will help reduce carbide precipitation. Carbide precipitation occurs when alloys containing both chromium and carbon are heated. The chromium and carbon combine to form chromium carbide (Cr_3C_2). The amount of chromium carbide formed is dependent on the percentage of carbon, the time that the metal is in the critical range, and the presence of stabilizing elements.

Wang (2008) mentioned that the mechanical and chemical properties of the stainless steel weldments are very important for the structure to exhibit their strength and anti-corrosion character. Hsaio (2008) added that welded structure made of stainless steel are commonly used in the power generation, oil and gas, marine transportation, petrochemical industries due to their higher mechanical strength and better corrosion resistance. Stainless steels are defined as iron base alloys which contain at least 10.5% chromium. The thin but dense chromium oxide film which forms on the surface of a stainless steel provides corrosion resistance and prevents further oxidation. There are five types of stainless steels depending on the other alloying additions present, and they range from fully austenitic to fully ferritic types (Nadzam, 2006).

Stainless steels are available in a wide range of product forms, such as plate, sheet, strip, precision strip, billet, engineering rounds, bar, rod, wire, pipe, tube, forgings, rings, castings, sections – hot rolled, extruded, drawn, cold formed, sintered products. The flat product forms can be obtained in a variety of surface finishes, and advice should be sought on the suitability of the different finishes for particular applications. Table 1.2 below show example of stainless steel grade (British stainless steel, 2001).

Table 1. 2: Stainless steel grade (British stainless steel, 2001)

FERRITIC					
1.4512	409S19	11% Cr + Ti	380	220	25
1.4016	430S17	17% Cr	430	250	20
1.4000	403S17	13% Cr + Al	400	230	19
MARTENSITIC					
1.4006	410S21	13% Cr 0.1% C	Normally supplied softened	-	-
1.4028	420S45	13% Cr 0.3% C	Normally supplied softened	-	-
DUPLEX					
1.4362	-	23% Cr 4.5% Ni	600	420	420
1.4462	-	22% Cr 5.5% Ni 3% Mo	660	480	20
AUSTENITIC					
1.4301	304S31} 304S16}	18% Cr	540	230	45
1.4307	304S15] 304S11	8.5% Ni 18% Cr 9% Ni Low C	520	220	45
1.4404	316S11	17% Cr 11% Ni 2% Mo	530	240	40
1.4541	321S31	17% Cr 9% N + Ti	520	220	40
SUPER AUSTENITIC					
1.4539		20% Cr 25% Ni 4.5% Mo + Cu	530	270	35
1.4547		20%Cr 18% Ni 6% Mo + Cu	650	320	35

1.2 Problem Statement

Based on the finding, there is only a few related with mechanical properties of the stainless steel weldments have been studied. There also hardly found the study on the microstructure of Heat Affected Zone (HAZ) and stainless steel weldment area. Beside that, only a few studied have been done to evaluate the effect of filler wire diameter on weldments of stainless steel.

1.3 Objectives

The objectives of the research are as follows:

- a) To study the effect of different ER308L filler wire diameter (0.8mm, 1.0mm, 1.2mm) on stainless steel AISI 304 weldments.
- b) To study the HAZ hardness area.
- c) To evaluate the microstructure behavior and conducted using Optical Microscope.
- d) To study the effect of different voltage setting (20V, 25V, 30V) on stainless steel weldment.

1.4 Scope of Study

The study of this paper will cover the behavior of material that will be weld in different size of ER308L filler wire diameter (0.8mm, 1.0mm, and 1.2mm). Stainless steel will be use as a base metal. The microstructure behavior is investigating and inspected using Optical Microscope. Type of joint the material is butt joint. Gas Metal Arc Welding (GMAW) or MIG welding is the equipment to joint the steel. The performance of each weldments specimen will be compared in term of behavior of microstructure and area of HAZ hardness by Rockwell Hardness test.

**ER stands for bare rod filler wire*

1.5 Important of Study

The purpose of the project is to investigate the influence of different electrode diameter on stainless steel microstructure. Since stainless steel has been used widely in manufacturing industry, the revolutionary of joining this part in industry has been developing. The good strength of weldment is needed. There fore the behavior of microstructure is investigating to find the mechanical properties of material and hardness of HAZ that occurred after joining process using MIG welding.