UNIVERSITI TEKNIKAL MALAYSIA MELAKA

THE STUDY OF E6013 ELECTRODE EFFECT ON MICROSTRUCTURE OF DIFFERENCE MILD STEEL THICKNESS BY USING ARC 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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I hereby, declared this thesis entitled "The Study of E6013 Electrode Effect on Microstructure of Difference Mild Steel Thickness by Using Arc Welding" is the result of my own research except as cited in references.

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Manufacturing Process) with Honours. The members of the supervisory committee are as follow:

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ABSTRACT

The research work conducted in this dissertation aims to evaluate mechanical properties (Hardness) and analysis Heat Affected Zone (HAZ) of mild steel A36 weldment. Here the welding was conducted based on three different thicknesses of specimen. The sizes are 4mm, 6mm and 8mm respectively. The arc voltage used consists of same value and the current flow for Shielded Metal Arc Welding (SMAW) was set the different values of 70A ~ 120A in range. Meanwhile the electrodes diameter for E6013 is 1/8in (3.1mm). The experiment started with preparing the specimen by welding process using SMAW welding equipment. The concentration initial is on preparing the plate specimen (total 9 specimens of different thickness) by cutting them into pieces of 120mm x 60mm. Response Surface Methodology was applied only research design and data analysis for hardness variation of weldment and HAZ. This investigation is used the advantages of manipulating the system as interrelation between the parameters of response to conduct experiment to get the highest of hardness result by calculating using software. Therefore, these experiments not cover the specific mathematical model, confirmation run and the standard method for the analysis. The relations then were compared with weldment hardness variation and microstructure using Image Analyzer that showed the transformation ferrite + pearlite to austenite at HAZ created a hard and brittle structure near the fusion zone. The result revealed that different current and thickness size applied could enforce the austenitic mild steel structure to an increasing strength in hardness and changes in microstructural contains.

ABSTRAK

Kajian yang bertajuk "The study of E6013 electrode effect on microstructure of difference mild steel thickness by using arc welding" telah pun dilaksanakan. Objektif utama perlaksanaan kajian ini adalah untuk menyiasat bagaimana parameter kimpalan mempengaruhi pembangunan struktur mikro dan ciri-ciri mekanikalnya terhadap kekerasan bahan besi. Proses kimpalan akan dilaksanakan menggunakan kaedah kimpalan arka logam. Latar belakang tentang pengetahuan didalam kimpalan arka logam secara terus termasuk bentuk bahan yang digunakan, sumber haba dan aplikasi komersialnya serta kesannya terhadap parameter proses turut dibincangkan. Eksperimen ini memanipulasikan pemboleh ubah (parameter kimpalan) iaitu arus elektrik dan ketebalan bahan ujukaji terhadap perubahan yang berlaku kepada pemboleh ubah yang bergerak balas iaitu struktur mikro dan variasi kekerasan. Ujikaji ini bersandar kepada kaedah kawalan dan manipulasi terhadap pemboleh ubah untuk menguji hipotesisnya. Akhirnya, variasi kekerasan akan diuji menggunakan ujian Rockwell dan struktur mikronya akan diuji menggunakan Optical Microscopy. Tambahan, penggunakan perisian Design Expert yang mengimplikasikan kaedah respon permukaan telah digunakan untuk menentukan keputusan yang terbaik dan optimum di dalam melaksanakan kajian ini. Kajian ini telah berjaya menganalisa kesemua data yang diperolehi daripada ujikaji yang dijalankan. Parameter proses seperti arus elektrik dan ketebalan bahan sangat mempengaruhi struktur mikro dan variasi kekerasan kimpalan yang terhasil. Akhir kata, cadangan untuk meningkatkan tahap optimum parameter yang digunakan di dalam eksperimen ini turut dibincangkan.

DEDICATION

Specially dedicated to my beloved family especially my father (Abdul Halim Bin Abdul Rahman) and my mother (Azizah Binti Ujang); whose very concern, understanding, supporting and patient. Thanks for everything. To my supervisor, En. Mohd Irman Bin Ramli for being receptive and critical, and challenging me to be a good student. To All My Friends, I also would like to say thanks. The Work and Success will never be achieved without all of you

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SMAW	-	Shielded Metal Arc Welding
GMAW	-	Gas Metal Arc Welding
HAZ	-	Heat Affected Zone
AISI	-	American Iron Standard Institute
SEM	-	Scanning Electron Microscopy
AWS	-	American Welding Society
UTeM	-	Universiti Teknikal Malaysia Melaka
PSM	-	Projek Sarjana Muda
ASTM	-	American Society for Testing and Materials
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
RAV	-	Rising arc Voltage
°C	-	Celsius
V	-	Voltage
A	-	Amperage

FZ-HAZ	-	Fusion Zone- HAZ
GG-HAZ	-	Grain Growth- HAZ
FG-HAZ	-	Fine-Growth- HAZ
IC-HAZ	-	Intercritical-HAZ
SC-HAZ	-	Subcritical- HAZ
DOE	-	Design of Experiment
DCEP	-	Direct Current Electrode Positive
DCRP	-	Direct Current Reverse Polarity
DCSP	-	Direct Current Straight Polarity

CHAPTER 1

INTRODUCTION

1.1 Introduction of Welding

Welding is a fabrication or sculptural process that joins materials, usually metals or thermoplastics, by causing coalescence. This is often done by melting the workpieces and adding a filler material to form a pool of molten material (the *weld pool*) that cools to become a strong joint, with pressure sometimes used in conjunction with heat, or by itself, to produce the weld.

Messler (2004) stated the welding first evolved as an important technique for fabricating metals, as part of the copper- and then brass- and then iron- making processes, as well as a principal means of making products from these metal joining small pieces into larger objects. Welding involves bringing the surface of metals to be joined closed enough together for atomic bonding to occur as the natural consequence of atoms seeking to create for themselves a stable electron configuration. In general, welding includes any process that causes materials to join through the attractive action of inter-atomic or inter-molecular forces as opposed to purely macroscopic or even microscopic mechanical interlocking forces.

Many different energy sources can be used for welding, including a gas flame, an electric arc, a laser, an electron beam, friction, and ultrasound. While often an industrial process, welding can be done in many different environments, including open air, under water and in outer space. Jeffus (2004) stated that the number of different welding processes has grown in recent year. These processes differ greatly in the manner in which heat, pressure, or both heat and pressure are applied and in the type of equipment used. Table B-1, list various welding and allied process (Appendix B). Some 67 welding process are listed, requiring hammering, pressing, or rolling to affect the coalescence in the weld joint. Other method brings the metal to fluid state and the edges flow together.

According to Song et al., (2003), welding has become a prevalent mechanical joining methodology in various industries because of its advantage over other joining methods including design flexibility, cost savings, overall weight reduction and structural performance enhancement. 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.

1.1.1 Shielded Metal Arc Welding (SMAW)

Shielded metal arc welding (SMAW) is an arc-welding process that fuses (melts) metal by heating it with an electric arc created between a covered metal electrode and the metals being joined. Shielded Metal Arc Welding had shown Figure. 1.1 is performed by striking an arc between a coated-metal electrode and the base metal. Once the arc has been established, the molten metal from the tip of the electrode flows together with the molten metal from the edges of the base metal to forma sound joint. This process is known as fusion. The coating from the electrode forms a covering over the weld deposit, shielding it from contamination (Jeffus, 2004).

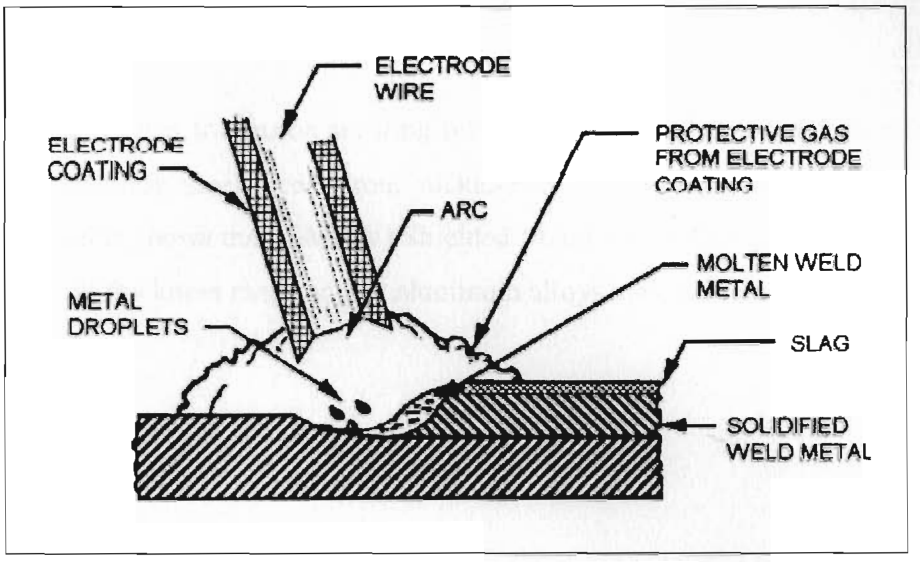

Figure 1. 1: Shielded Metal Arc Welding (SMAW) (Jeffus, 2004)

Shielded Metal Arc welding is one of the most widely used processes, particularly for short welds in production, maintenance and repair work, and for field construction. The following are advantages of this process:

- The equipment is relatively simple, inexpensive, and portable.
- The filler metal, and the means of protecting it and the weld metal from harmful oxidation during welding, is provided by the covered electrode.
- Auxiliary gas shielding or granular flux is not required.
- The process is less sensitive to wind and draft than gas shielded arc welding processes.
- It can be used in areas of limited access.
- The process is suitable for most of the commonly used metals and alloys.

1.1.2 Welding Process and Materials

Table 1.1 summarizes the fusion welding process recommended for carbon steel, low-alloy steel, stainless steels, cast iron, nickel-base alloys, and aluminum alloy. For instance, the table shows that (SMAW) Shielded Metal Arc Welding is applicable for all materials for all thickness range accept aluminum alloys material (Kou, 2003).

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

Material	Thickness[b]	SMAW	SAW	GMAW	FCAW	GTAW	PAW	ESW	OFW	EBW	LBW
Carbon steels	S	×	×	×		×			×	×	×
	I	×	×	×	×	×			×	×	×
	M	×	×	×	×				×	×	×
	T	×	×	×	×			×	×	×	
Low-alloy steels	S	×	×	×		×			×	×	×
	I	×	×	×	×	×				×	×
	M	×	×	×	×					×	×
	T	×	×	×	×			×		×	
Stainless steels	S	×	×	×		×	×		×	×	×
	I	×	×	×	×	×	×			×	×
	M	×	×	×	×		×			×	×
	T	×	×	×	×			×		×	
Cast iron	I	×							×		
	M	×	×	×	×				×		
	T	×	×	×	×				×		
Nickel and alloys	S	×		×		×	×		×	×	×
	I	×	×	×		×	×			×	×
	M	×	×	×			×			×	×
	T	×		×				×		×	
Aluminum and alloys	S			×		×	×		×	×	×
	I			×		×				×	×
	M			×		×				×	
	T			×						×	