A STUDY ON THE EFFECT OF HEAT SUPPLY ON THE MICROSTRUCTURE OF HEAT AFFECTED ZONE(HAZ) USING MIG

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DECLARATION

I Dayang Nur Fitri Emyra Binti Abdul Aziz (BK18110086) hereby declare that this (Thesis Draft Report entitled "A Study on the Effect of Heat Supply on Microstructure of Heat Affected Zone (HAZ) using MIG", submitted to Universiti Malaysia Sabah, as an original work, except for extracts which the original references are stated herein under the supervision of Mr. Abdullah Mohd. Tahir.

1st August 2022

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DECLARATION BY SUPERVISOR

I declare that this Thesis Draft Report entitled "A Study on The Effect of Heat Supply on Microstructure of Heat Affected Zone (HAZ) using MIG" was written by the above candidate in the accordance with the rules and regulations established by the Faculty of Engineering, Universiti Malaysia Sabah.

1st August 2022

Abdullah Mohd. Tahir

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ABSTRACT

In the engineering industry, welding is mostly used to create steel structures. There are many benefits to welding, including simple setup, great mobility, low manufacturing costs, and high welded joint efficiency. When it comes to joining ferrous and non-ferrous metals together during the welding process, Metal Inert Gas welding (MIG) is a remarkably dependable alternative to compare with the other welding techniques. The microstructure of the heat affected zone (HAZ) is the key aspect of this study that needs proper examination because it is believed that different heat supplies and different cooling methods would have varying effects on its HAZ. The parameter of this investigation includes mild steel filler rod (ER70S-6), carbon dioxide shielding gas, single pass welding, and mild carbon steel base metal. The advantages of using mild carbon steel are numerous. Most industrial sectors can use it to a great extent. It is very weldable, machinable, impressively strong, and has good ductility. This study will considerably benefit from the choice of this steel because it is inexpensive, simple to get, and simple to weld. Due to its high weldability property, the microstructure analysis done on this material grade will undoubtedly result in a proper finding at the conclusion of this research. Prior to taking optical images, the samples were carefully cleaned after the production process by grinding, polishing, and etching. An observational comparison study was done using the images that were obtained. Heat supply and microstructure's interaction was demonstrated to be parallel to one another. A slow and steady cooling method with a lower heat supply is expected to result in the formation of a finer microstructure and, by prediction, a stronger HAZ region with high toughness, high hardness, and high brittleness, while a rapid cooling method with higher heat supply results in the formation of a coarser microstructure and, by prediction, a weaker HAZ region with low toughness, low hardness, and low brittleness.

ABSTRAK

Dalam industri kejuruteraan, kimpalan kebanyakannya digunakan untuk mencipta struktur keluli. Terdapat banyak faedah untuk mengimpal, termasuk persediaan mudah, mobiliti yang hebat, kos pembuatan yang rendah dan kecekapan sambungan kimpalan yang tinggi. Apabila ia datang untuk menggabungkan logam ferus dan bukan ferus bersama-sama semasa proses kimpalan, kimpalan Gas Lengai Logam (MIG) adalah alternatif yang boleh dipercayai untuk dibandingkan dengan teknik kimpalan yang lain. Struktur mikro zon terjejas haba (HAZ) adalah aspek utama kajian ini yang memerlukan pemeriksaan yang sewajarnya kerana dipercayai bahawa bekalan haba yang berbeza dan kaedah penyejukan yang berbeza akan memberi kesan yang berbeza-beza pada HAZnya. Parameter penyiasatan ini termasuk rod pengisi keluli lembut (ER70S--6), gas pelindung karbon dioksida, kimpalan laluan tunggal dan logam asas keluli karbon lembut. Kelebihan menggunakan keluli karbon ringan adalah banyak. Kebanyakan sektor perindustrian boleh menggunakannya secara meluas. Ia sangat boleh dikimpal, boleh dimesin, sangat kuat, dan mempunyai kemuluran yang baik. Kajian ini akan mendapat banyak manfaat daripada pilihan keluli ini kerana ia adalah murah, mudah diperoleh dan mudah dikimpal. Oleh kerana sifat kebolehkimpalannya yang tinggi, analisis struktur mikro yang dilakukan pada gred bahan ini sudah pasti akan menghasilkan penemuan yang tepat pada akhir penyelidikan ini. Sebelum mengambil imej optik, sampel dibersihkan dengan teliti selepas proses pengeluaran dengan mengisar, menggilap dan mengetsa. Kajian perbandingan pemerhatian telah dilakukan menggunakan imej yang diperolehi. Bekalan haba dan interaksi struktur mikro telah ditunjukkan selari antara satu sama lain. Kaedah penyejukan yang perlahan dan mantap dengan bekalan haba yang lebih rendah dijangka menghasilkan pembentukan struktur mikro yang lebih halus dan, mengikut ramalan, kawasan HAZ yang lebih kuat dengan keliatan tinggi, kekerasan tinggi dan kerapuhan tinggi, manakala kaedah penyejukan pantas dengan haba yang lebih tinggi bekalan menghasilkan pembentukan struktur mikro yang lebih kasar dan, mengikut ramalan, kawasan HAZ yang lebih lemah dengan keliatan rendah, kekerasan rendah dan kerapuhan rendah.

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LIST OF ABBREVIATIONS

HAZ	-	Heat Affected Zone
SEM	-	Scanning Electron Microscope
MIG	-	Metal Inert Gas
PPE	-	Personal Protective Equipment
GTAW	-	Gas Tungsten Arc Welding
TIG	-	Tungsten Inert Gas
FCAW	-	Flux-Cored Arc Welding
MAG	-	Metal Active Gas
CO2	-	Carbon Dioxide
MMA	-	Manual Metal Arc
MAG	-	Metal Active Gas
ER 70S-6	-	"ER" electrode, "70" tensile strength 70,000psi, "S" solid wire
GMAW	-	Gas Metal Arc Welding
SMAW	-	Shielded Metal Arc Welding
SS	-	Stainless Steel
LCS	-	Low Carbon Steel
PWHT	-	Post-Weld Heat Treatment
AISI	-	American Iron and Steel Institute
HAZH	-	Heat Affected Zone Hardness
SiO2	-	Flux-Cored Arc Welding
SAW	-	Submerged Arc Welding
ST12	-	Carbon Dioxide
AC	-	Alternating Current
HSLA	-	High Strength Low Alloy
EDX	-	Energy Dispersive X-Ray Analysis
AWS	-	American Welding Society
1G	-	Flat Groove

HRA	-	Hardness Rockwell Scale A
CGHAZ	-	Coarse Grained Heat Affected Zone
FGHAZ	-	Fine Grained Heat Affected Zone
ICHAZ	-	Inter Critical Heat Affected Zone
SCHAZ	-	Sub-Critical Heat Affected Zone
PF	-	Polygonal Ferrite
WF	-	Widmanstatten Ferrite
AF	-	Acicular Ferrite

LIST OF SYMBOLS

V	-	Voltage
I	-	Current
A	-	Ampere
mm	-	Micro Meter
v	-	Volt
kJ	-	Kilo Joule
V	-	Voltage
I	-	Current

CHAPTER 1

INTRODUCTION

1.0 Introduction

Welding is a permanent joining method that uses heat, pressure, or both to fuse like or different materials (Kumar et al., 2021). Welding has a number of advantages, including the ease of setup, high mobility, low manufacturing costs, and high welded joint efficiency. Among the welding methods, the Metal Inert Gas (MIG) welding technique is the most commonly used welding technology in the industry. MIG welding uses an electrode all of the time, which is why a trigger regulating device is utilised to control the wire feed and wire bob in this type of soldering procedure. MIG soldering is commonly used in manufacturing operations where output rates are high and there is a high risk of arc or shape gas loss due to wind air (Madavi et al., 2021).

In order to carry out the welding operation, a heat supply is required in every instance. The electrical power supplied to the work piece by the weld arc is known as the heat supply. The heat source is changed in this experiment by altering the current provided to the welding set. Equation 1 is used to compute the theoretical heat supply:

$$Heat\ Supply = \frac{Current \cdot Voltage \cdot 60}{Speed\ \cdot 1000} \tag{1}$$

The unit for arc voltage is volt (V), welding speed is mm/min, welding current in Ampere (A), and the unit for heat supply is kJ/mm where kJ stands for kilo Joule.

The heat affected zone (HAZ) is the non-molten portion of metal that has undergone changes in microstructure and material properties as a result of exposure to high temperatures (Shi et al., 2014). Fabricators and operators are concerned about the heat-affected zones (HAZ) of high-strength steel weldments because of the risk of fracture initiation in this area, particularly the coarse-grained HAZ (Asadi et al., 2021). The HAZ is described as the unaffected area between the weld and the base. Depending on the qualities of the materials, the quantity of heat supplied, and the welding procedure used, the HAZ area might vary in severity and size. The microstructure and characteristics of this region vary as a result of the heating that occurs within the HAZ, and they differ from those of the underlying material. Depending on the substance, these changes are usually unwanted and unavoidable (Gáspár, 2019).

1.1 Problem Statement

In the welding industry, when it comes to analysing the strength of weldments, the microstructure of it is frequently disregarded. Therefore, the goal of this project is to investigate the changes in the microstructure of the Heat Affected Zone (HAZ) for connected mild carbon steel when a different heat supply and different cooling methods are applied by the Metal Inert Gas (MIG) welding and to find the relationship between the effect of current to the heat supply. The project's conclusion will aid in the quality control and quality assurance of weldments for the specified welding parameters on the mild steel application specifically for gates and fencing that need to be both secure and appealing.

1.2 Research Objectives

The objectives of this projects are:

i) To examine and analyse the microstructure of heat-affected zones (HAZ) using optical microscope when different heat supplies and different cooling methods are applied.

ii) To correlate the heat-affected zone (HAZ) region microstructure with the welding operation parameters (current and heat supply).

1.3 Research Scope of Works

1.3.1 Steel plates are welded using MIG welding with a consumable electrode

Mild carbon steel is the sort of plate material that will be used. The plate dimension should be around 210mm X 50mm x 4mm, but this can vary depending on the source. The procedure is carried out with different voltages, and the welding speed is measured and determined by dividing the distance travelled by the time.

1.3.2 Optical Microscope is used to analyse the microstructure of the welded joint in the Heat Affected Zone (HAZ).

Optical Microscope and Scanning Electron Microscope (SEM) will be used for metallurgical analysis, but SEM will only be used if the microstructure of the HAZ of welded mild steel cannot be seen through optical microscope. This is because as to compare between the optical microscope and SEM, many structures can no longer be described by light microscopy as materials and devices reduce in size, but can be done by SEM since it has a greater magnification with 20X to 30,000X magnification, 50 to 100nm spatial resolution. The microimaging technology works by focusing electrons across a surface and creating a picture as the electrons produce various signals once they come into contact with the sample. The information gathered will represent the surface's topography and composition (Velasco & Velasco, 2013). If the metallurgical analysis can be done using the optical microscope located in *Pusat Rencam* of Faculty of Engineering, Universiti Malaysia Sabah then SEM procedure will not be proceeded. If in any case the SEM need to be conducted then the samples will be sent to *Insitut Penyelidikan and Bioteknologi*, Universiti Malaysia Sabah.

1.4 Research Methodology

1.4.1 Material and Equipment

The list of materials and equipment required for this project;

a) Mild steel plates
b) Metal Inert Gas (MIG) Welding Set
c) Gloves, Safety Boots and Face Shield (PPE)
d) Scanning Electron Microscope

1.4.2 Sample Preparation

This study will be carried out primarily at the University of Malaysia Sabah, using the MIG welding set in the Faculty of Engineering workshop. The welding workshop will provide the mild steel plates. Rust, dirt, coolant, or grease will almost certainly stain the plates that are obtained. All of these contaminants on the steel plate's surface will prevent the weld from properly joining to the metal piece. Prior to welding, the obtained mild steel work piece must be thoroughly cleaned. During the welding process, the single pass method is used. The variable that is manipulated is the current, which is varied for each sample to change the amount of heat supplied to the samples.

1.4.3 Sampling and Lab Testing

The Optical Microscope is the laboratory equipment that will be used to continue this investigation for sampling and lab testing.

1.4.4 Data Analyzation

In order to evaluate, comprehend, and present the findings in a more complete manner, a qualitative technique is chosen for data analysis. All of the experiment's test results will be tabulated for additional analysis and brainstorming.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Welding has a long and illustrious history dating back to antiquity. The oldest evidence of welding can be found in the Bronze Age. Little gold circular boxes were created by pressing lap joints together. The age of these boxes is estimated to be around 2,000 years. During the Iron Age, Egyptians and residents of the eastern Mediterranean learned to weld iron pieces together. Many tools dating back to roughly 1000 B.C. have been unearthed (Lau et al., 1986).

During the Middle Ages, innumerable iron artefacts were made and hammered together, giving rise to the art of blacksmithing. Welding as we know it today dates from the nineteenth century. Edmund Davy of England is credited with discovering acetylene in 1836. Around 1800, Sir Humphry Davy is credited with using a battery to create an arc with two carbon electrodes. In the mid-nineteenth century, the electric generator was invented, and arc lighting became widespread. In the late 1800s, gas welding and cutting were invented. After the invention of arc welding with the carbon arc and metal arc, resistance welding became a viable joining method (Miller Welds, 2016).

In general, early civilizations began with copper, progressing to bronze, silver, gold, and iron over time. Moving on, traditional welding was not invented until the nineteenth century. Humans have been developing more and more dependable welding processes since the 19th century for accurate, rapid, and effective welding. We now have robotic welding, a process that is gaining popularity that uses computer control to weld metal considerably faster and accurate than manual welding. Despite