UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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EFFECTS OF ARGON SHIELDING GAS FLOW RATE ON WELDING QUALITY OF MILD STEEL

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A thesis submitted
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DECLARATION

I declare that this thesis entitled "Effects of Argon Shielding Gas Flow Rate on Welding Quality of Mild Steel" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Name	:	NUR HIDAYAH BINTI ZULKIPLI
Date	:	……………………………………...

APPROVAL

I hereby declare that I have read this dissertation/report and in my opinion this dissertation/report is sufficient in terms of scope and quality as a partial fulfilment of Master of Manufacturing Engineering (Industrial Engineering).

Signature	:	…………………………………...
Name	:	……………………………………
Date	:	……………………………………

DEDICATION

I dedicated this to my respected supervisor, Prof. Madya Dr. Md Nizam bin Abd Rahman for the unwavering guidance, support and encouragement, my beloved parents, Mr Zulkipli bin Saad and Mrs Noor Ashikin binti Abdul Rahman for being very supportive in terms of encouragement and finance during the completion of this thesis. I also dedicated this to all of the technicians in Faculty of Manufacturing Engineering for their timeless help especially to Mr Nizamul, Mr Mazlan, Mr Hanafiah, Mr Ghazalan, Mrs Norzuriyahni, Mr Hairulhisham and Mr Taufik. Last but not least, I dedicated this to my fellow friends for their help and impetus of encouragement towards me in the completion of this thesis.

ABSTRACT

Welding is a method to join two or more parts permanently. Gas Metal Arc Welding (GMAW) also known as Metal Inert Gas (MIG) is one of the process in welding. In GMAW, there are a continuously solid wire electrode that come together with shielding gas. There are several type of shielding gases in welding industry, but the most commonly used are argon, helium, carbon dioxide and oxygen. The function of shielding gas in welding operation is to protect the weld pool from oxidation. Shielding gas types also plays an important role in producing a good quality of welding as each of them have different advantages and disadvantages. There are several studies that have been done to study the effects of shielding gases and their combination on welding quality, but there is lack of study on how flow rate of pure argon gas may affects the quality of the welding. The purpose of this study is to identify the effects of different flow rates of argon gas on welding quality and to suggest the best flow rate of argon gas within the evaluated range. There are three type of welding characterizations in determining the welding quality that have been investigated which are strength, hardness and microstructure of the welded sample. In order to observe and determine the welding characterizations, three tests have been used which are tensile, microhardness and microstructure test respectively. Minitab17 (Analysis of Variance (ANOVA) and boxplot) is the tool that has been used to analyse the data and result of the tests. From the result obtained, the sample welded with 45 SCFH flow rate of argon gas has the highest strength and hardness value compare to the others. As the conclusion, it is suggested that the best flow rate of argon gas within the evaluated range is 45 SCFH. There are some recommendations for a better future study that have been recommended in the last chapter of this report.

ABSTRAK

Kimpalan adalah satu kaedah untuk melekatkan dua atau lebih bahagian secara kekal. Kimpalan Arka Logam Gas (GMAW) juga dikenali sebagai Gas Inert Logam (MIG) adalah salah satu proses dalam kimpalan. Dalam GMAW, terdapat satu dawai padat berterusan yang hadir bersama gas pelindung. Terdapat beberapa jenis gas pelindung dalam industri kimpalan, tetapi yang sering digunakan adalah argon, helium, karbon dioksida dan oksigen. Fungsi gas pelindung dalam operasi kimpalan adalah untuk melindungi kolam kimpalan dari pencemaran. Gas pelindung juga memainkan peranan yang penting dalam menghasilkan kualiti kimpalan yang bagus kerana masing-masing mempunyai kebaikan-kebaikan dan keburukan-keburukan yang berbeza. Terdapat beberapa kajian yang telah dijalankan untuk mengkaji kesan-kesan gas-gas pelindung dan kombinasi mereka terhadap kualiti kimpalan, namun terdapat kekurangan kajian terhadap bagaimana kadar aliran argon tulen boleh menjejaskan kualiti kimpalan. Tujuan kajian ini adalah untuk mengenalpasti kesan-kesan kadar aliran gas argon yang berbeza terhadap kualiti kimpalan dan untuk mencadangkan kadar aliran gas argon yang terbaik dalam linkungan yang dinilai. Terdapat tiga jenis pencirian kimpalan dalam menentukan kualiti kimpalan yang perlu diperhatikan iaitu kekuatan, kekerasan dan mikrostruktur sampel yang dikimpal. Sebagai untuk memerhatikan dan menentukan pencirian kimpalan, tiga ujian akan digunakan untuk masing-masing iaitu ujian tegangan, kekerasan dan mikrostruktur. Minitab17 (Analisis variasi (ANOVA) dan plot kotak) adalah alat yang akan digunakan untuk menganalisis data dan keputusan ujian-ujian tersebut. Dari keputusan yang telah diperolehi, sampel yang dikimpal dengan 45 SCFH kadar aliran gas argon mempunyai nilai kekuatan dan kekerasan yang paling tinggi berbanding dengan yang lain. Sebagai kesimpulannya, kadar aliran gas argon yang terbaik dalam lingkungan yang dinilai adalah 45 SCFH. Terdapat beberapa cadangan untuk kajian pada masa hadapan yang lebih baik telah diberikan dalam bab terakhir laporan ini.

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CHAPTER 1

INTRODUCTION

1.1 Background

Gas Metal Arc Welding (GMAW), also known as Metal Inert Gas (MIG) welding was developed in the 1940's. It is a process in which a continuously solid wire electrode is utilizes through a welding gun, shielding gas from an externally supplied source, and also electrical power to melt the electrode and thus deposit this molten material in the weld joint. In order to protect the weld pool from oxidation, a shielding gas is sent through the welding gun. The arc plasma is forms by the shielding gas, stabilizes the arc on the metal after being welded, shields the arc and molten weld pool and thus allows smooth transfer of metal from the weld wire to the molten weld pool. When using MIG welding, only inert gases or gas mixtures are used for the shielding gas (Mvola and Kah, 2016). Figure 1.1 shows the MIG welding.

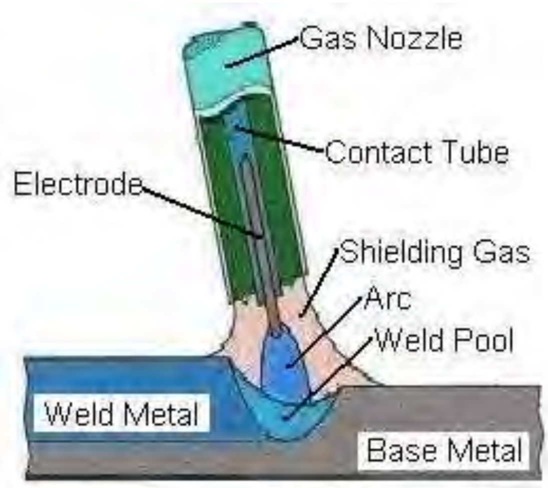

Figure 1.1: MIG Welding (Mvola and Kah, 2016)

The process melts and fuses metals using the intense heat generated by an electric arc between the metals to be joined and a filler wire (solid or flux cored). The wire is dynamically melted at a similar speed at which it is being nourished by the wire feeder and structures some portion of the weld pool. Both the arc and the weld pool are protected against atmospheric contamination by a shield of inert (non-reactive) gas.

There are four most common shielding gases used in MIG welding which are Argon, Helium, Carbon Dioxide and Oxygen. They come with each providing unique benefits and drawbacks in any given application. There are various effects of shielding gas on welding quality. For example, weld metal porosity due to gas coverage, improper surface condition and base metal properties, improper weld bead profile due to insufficient heat input, technique and inadequate work cable, lack of fusion due to cold lapping in the short arc transfer process, faulty wire delivery due to contact tip, gun liner, worn out gun, drive roll and wire coming off reel and tangling (Chem and Chen, 1998).

It is important to choose type of shielding gas that want to be use and the optimal flow rate of shielding in order to obtain good weld quality. In addition, by installing an optimal flow rate of shielding gas, it can save the cost and directly give impact on the operating efficiency and also profitability (Mvola and Kah, 2016). Without consideration of the gas waste, the estimation cost of shielding gas is about 5-7 % while with the consideration of the gas waste, the shielding gases cost could reach 25 % of the overall cost of welding process (Mvola and Kah, 2016).

MIG welding is very useful because it can be used for various types of metals such as carbon steel, stainless steel, aluminium, magnesium, copper, nickel, silicon bronze and other alloys. In addition, there are some advantages of MIG welding such as the ability to join a wide range of metals and thicknesses, all-position welding capability, a good weld bead, a minimum of weld splatter and it is easy to learn.

1.2 Problem Statement

As the names stated "Metal Inert Gas Welding", MIG welding requires a shielding gas to be used as there is no shielding on the electrode or filler wire. Without shielding gas, MIG welding would not be possible. Different flow rates of Argon shielding gas play an important role in determining weld penetration profiles, arc stability, mechanical properties of the finished weld and more (Zhang et al., 2006). The reaction of different flow rates of Argon gas with the weld pool can create a variety of problems, including porosity, (holes within the weld bead) and excessive spatter. Inadequate flow of shielding gas can caused porosity and dramatically can weaken the weld (Ley et al., 2015).

Different flow rates of Argon gas can also affect the transfer of the filler metal from the arc to the weld joint, which in turns contributes to the efficiency of the welding process and the quality of the weld (Machida et al., 1998). Other important factors that different flow rates of argon gas help determine include the weld bead appearance, and weld toughness and strength.

Pires et al., (2007) study the effect of seven types of shielding gas involving argon carbon dioxide on the fume formation rate. Mohd. Shoeb et al., (2013) studied the effect of shielding gas parameters on weld bead geometry in which involving argon, carbon dioxide and oxygen shielding gas. Ley et al., (2015) studied the effect of shielding gas parameters on post weld thermal properties by using argon, carbon dioxide and helium gas. Rao et al., (2010) studied the effect of shielding gas composition onto weld pool, weld pool dynamics and weld bead profiles by using three composition of shielding gas involving argon and helium. Reichelt (1980) studied the effect of shielding gas composition and flow rate on arc gap, current, voltage, penetration, arc stability and porosity by using argon and helium as the shielding gas.

There are several researchers that study on the effect of shielding gases composition on the welding quality, but, there is lack of study on the effect of shielding gas flow rate on welding quality by using pure argon as the variable. Therefore, the effect of shielding gas flow rate of argon will be analysed in this study.

1.3 Project Questions

1. What are the effects of different flow rates of argon shielding gas on welding quality of mild steel?
2. What is the optimal flow rate of argon shielding within the evaluated range?

1.4 Objectives

1. To identify the effects of different flow rates of argon shielding gas on welding quality of mild steel.
2. To suggest the best flow rate of argon gas within the evaluated range.

1.5 Scope

The type of welding operation in this study is Gas Metal Arc Welding (GMAW). This study is focused only on one type of shielding gas which is Argon gas. The welding experiment will be carried out by using robotic arc welding with different flow rates of argon gas. The type of material used in this study is mild steel plate.

CHAPTER 2

LITERATURE REVIEW

2.1 Welding

Welding is a method of joining two or more parts permanently. The join is at their touching surfaces by applying a suitable heat and/or pressure. Usually, a filler wire is being used together in order to enable coalescence. The joined parts are called a weldment. Primarily, welding is used in metal parts and their alloys (Ebrahimnia et al., 2009).

There are two major groups are classified in welding process. The first group is fusion welding and the second group is solid-state welding. Table 2.1 listed the differences between fusion welding and solid-state welding (Thomas et al., 1998). In this study, arc welding is used as the method of joining two or more metal parts permanently. In arc welding method, there are several welding processes such as:

- Gas Metal Arc Welding (GMAW)
- Shielded Metal Arc (SMAW) or Stick Welding
- Submerged Arc Welding (SAW)
- Flux Cores Arc Welding (FCAW)
- Gas Tungsten Arc Welding (GTAW)
- Plasma Arc Welding (PAW)
- Oxyfuel Gas Welding (OFW)
- Laser Beam Welding (LBW)
- Friction Welding (FRW)
- Diffusion Bonding (DB)
- Explosion Welding (EXW)
- Ultrasonic Welding (USW)
- Electro Slag Welding (ESW)
- Electro Gas Welding (EGW)
- Electron Beam Welding (EBW)

Table 2.1: Differences between Fusion Welding and Solid-state Welding

Fusion Welding	Solid-state Welding
• Base metal is melted by means of heat. • Filler metal is added to the molten pool in order to facilitate the process and provide bulk and strength to the joint. • Commonly used are: ✓ Arc welding ✓ Resistance welding ✓ Oxyfuel welding ✓ Electron beam welding ✓ Laser beam welding	• Joining of parts takes place by application of pressure alone or a combination of heat and pressure. • No filler metal is used. • Commonly used are: ✓ Diffusion welding ✓ Friction welding ✓ Ultrasonic welding

Melting and fusing the adjacent portions of the separate parts will lead to a homogenous joint. The unit strength of the final welded joint is approximately equal to that of the base material. To prevent oxidation, a flux material is used, which decomposes under the heat of welding and a gas that shields the arc and the hot metal is released (Slavkov and Magdeski, 2003).

2.2 GMAW Welding

Nowadays, the gas metal arc welding (GMAW) process has been controlling the welding construction world. This fact is stated by Pires et al., (2007) due to its high flexibility, in which allows the welding of a great variety of materials and thickness, and also its considerable potential for both automation and robotization. According to Pires, (2007) the most frequently used welding processes is MIG, also known as GMAW which is about 70% of the welding jobs.

Gas metal arc welding (GMAW), also known as metal inert gas (MIG) welding when referred to by its subtypes. It is a welding process in which melt and joint workpiece metal(s) by using a consumable wire electrode to heat the work piece metal(s). Along with the wire electrode, a shielding gas feeds through the welding gun, which shields the process from contaminants in the air (Litwin et al., 2017). The process can be semi-automatic or automatic. A constant voltage, direct current power source is most commonly used with GMAW, but constant current systems, as well as alternating current, can be used. There are four primary methods of metal transfer in GMAW, called globular, short-circuiting, spray, and pulsed-spray, each of which has distinct properties and corresponding advantages and limitations (Vanaja, 2017).

The chief advantages in using GMAW for surfacing are all position capability, high reliability low cost, ease of use and high productivity compare to the other welding process, (Mohd. Shoeb et al., 2013). Due to this advantages of MIG welding, it has been employed increasingly in mechanized surfacing in industry.

According to Rao et al., (2010), in GMAW, there are three basic modes to transfer the metal from electrode tip such as:

- Short-circuit transfer
- Globular transfer
- Spray transfer

In globular mode, there is a transfer rate of a few droplets per second and the diameter of droplet is larger than the electrode. Currently, the spray mode has replace the metal transfer mode due to the characterization of very small droplets and presence of high detachment frequency.

When comparing to other welding process, GMAW provided faster welding time so that it become popular in welding all types of steel. Nowadays, GMAW become number one in industrial welding process due to its speed, versatility, and easy to adapt the process by using robotic automation (Vanaja, 2017).

2.3 Parameter of GMAW

The chemical composition and the amount of the fumes produced depend on the welding parameters. The type filler wire, current intensities range, voltages and electrode polarity influence the metal transfer mode (Pires et al., 2007). As mentioned before, the most frequently used welding process is MIG welding, thus, work on reduction of fumes at the source must be focussed on these processes. Pires et al., (2007) claim that proper selection of welding parameters can help in reducing the welding fumes. According to Mohd. Shoeb et al., (2013) the parameters considered in GMAW are welding current, arc voltage, welding speed, nozzle to plate distance and gin angle. When study about the gas flow rate, the optimal welding speed and arc voltage are 36 cm/min and 32 V respectively.

In MIG welding, parameters are the most important factors that will affect the productivity, quality, and cost of welding process. The welding parameters include welding voltage, welding current, wire feed rate, gas flow rate, etc. that will influence and give impact to the weld pool geometry and weld strength of the steel material during welding operation (Vanaja, 2017).