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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

# Investigation of Welding Parameters Effect on Welding Distortion of Conventional Gas Metal Arc Welding (GMAW) and Cold Arc

Submitted in accordance with the requirement of the University Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Manufacturing Engineering)(Hons.)

by


**SYARMINE AFIQAH BINTI AZMAN**

**B051410298**

**951126-10-5240**

FACULTY OF MANUFACTURING ENGINEERING


2018

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Tajuk: **INVESTIGATION OF WELDING PARAMETERS EFFECT ON WELDING DISTORTION OF CONVENTIONAL GAS METAL ARC WELDING (GMAW) AND COLD ARC**

Sesi Pengajian: **2017/2018 Semester 2**

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Signature : ..................................................

Author's Name : SYARMINE AFIQAH BINTI AZMAN

Date : 21 MAY 2018

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# APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Hons.). The members of the supervisory committee are as follow:

.................................................

(PM Dr. Nur Izan Syahriah Binti Hussein)

ASSOCIATE PROFESSOR DR. NUR IZAN SYAHRIAH BINTI HUSSEIN
DEPUTY DIRECTOR
Life Long Learning Centre
Universiti Teknikal Malaysia Melaka
Hang Tuah Jaya
76100 Durian Tunggal, Melaka

.................................................

(Mohamad Nizam Bin Ayof)

MOHAMAD NIZAM BIN AYOF
Felow
Pusat Pembelajaran Sepanjang Hayat (PPSH)
Universiti Teknikal Malaysia Melaka

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# ABSTRAK

Kajian ini membincangkan tentang operasi kimpalan terhadap plat nipis yang mempunyai ketebalan yang berbeza. Matlamat kajian ini adalah untuk menentukan proses kimpalan yang sesuai dan terbaik untuk diaplikasikan dalam industri automotif dengan membandingkan kesan parameter kimpalan terhadap sifat tegangan dan maksrostruktur spesimen hasil proses kimpalan GMAW dan cold arc. Pada masa yang sama, rekabentuk dan fabrikasi jig kimpalan juga terlibat bagi mengapit bahan kerja dengan ketebalan 0.8 mm. Rekabentuk pengapit dan bahan jig kimpalan telah dikaji bagi menjana konsep jig kimpalan GMAW. Selain itu, matriks perancangan parameter kimpalan iaitu arus kimpalan, voltan kimpalan, dan kelajuan kimpalan telah dihasilkan melalui Response Surface Method (RSM). RSM telah dipilih untuk memberi optimum parameter yang terbaik serta hubungkait yang jelas antara parameter dan tindak balas. Ukuran panjang herotan kimpalan yang dipotong dalam bentuk mengikut ukuran telah diukur menggunakan CNC Coordinate Measuring Machine. Ukuran panjang tersebut berguna untuk menyiasat kekuatan ikatan bahan antara proses GMAW yang menggunakan atau yang tidak menggunakan arus kimpalan yang rendah.



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# ABSTRACT

This study deals with the arc welding operation of thin plate with different thickness. The aim of this study is to determine the suitable welding process to be applied in automotive industry by comparing the effect of welding parameters on the tensile properties and macrostructure of welded specimen of Gas Metal Arc Welding (GMAW) and cold arc process. At the same time, the design and fabrication of welding jigs also involve clamping workpiece with the thickness up to 0.8 mm. Clamping design and common welding jigs material was studied in order to design and generate concept for the GMAW welding jigs. On the other hand, a planning matrix of the welding parameters which is arc current, arc voltage and welding speed was developed by Response Surface Method (RSM). RSM is chosen to give the best optimization parameters and a clear link between parameters and response. The length of welding distortion of the welded specimen which is cut with required dimension for both processes were measured by using CNC Coordinate Measuring Machine. The distortion length is useful to investigate the strength of bonding of the material between GMAW operation with or without the use of low arc current.



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# DEDICATION

Specially dedicated to my beloved parents, Azman Hashim and Fairus Binti Adam who gives motivational support and strength to me throughout this semester to complete the final year project.



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# ACKNOWLEDGEMENT

In the name of ALLAH, the most gracious, the most merciful, Alhamdulillah with the highest praise to Allah that I manage to complete this final year project successfully without difficulty.

My respected supervisor, Professor Madya Dr. Nur Izan Syahriah Binti Hussein for the great mentoring that was given to me throughout the project. Besides that, I would like to express my gratitude to my hardworking co-supervisor, Mr. Mohamad Nizam Bin Ayof for his kind supervision, advice and guidance as well as exposing me with meaningful experiences throughout the study.

Last but not least, I would like to give a special thanks to my best friends who gave me much motivation and cooperation mentally in completing this report especially to, welding technician, Mr. Nizamul for giving a technical lesson on how to use both of the robot welding KUKA and OTC and permission using equipments throughout the whole semester. Besides, Mr. Saifuldin, phd student who guide and taught me a lot in this project for theoretical advice, experimental guidance and help to overcome every issue that occur during the experiment and my beloved parents for financial support. They had given their critical suggestion and comments throughout my research. Thanks for the great synergy.

Finally, I would like to thank everybody who was important to this FYP report, as well as expressing my apology that I could not mention personally each one of you.



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# LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| ANOVA | - | Analysis of Variance |
| AWS | - | American Welding Standard |
| CMT | - | Cold Metal Transfer |
| DOE | - | Design of Experiment |
| GMAW | - | Gas Metal Arc Welding |
| GTAW | - | Gas Tungsten Arc Welding |
| MIG | - | Metal Inert Gas |
| RSM | - | Response Surface Methodology |
| SMAW | - | Submerged Metal Arc Welding |
| STT | - | Surface Tension Transfer |



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# CHAPTER 1

# INTRODUCTION

## 1.1 Background Study

Welding is processes in which materials of the same fundamental type or class are brought together and caused to join become one through the formation of primary chemical bonds under the combined action of heat and pressure (Messler, 2008). According to Messler (2008), when significant is involved and necessary for welding to involve, the processes are called fusion welding processes. There are 3 type of fusion welding which is gas welding, arc welding and high-energy beam welding. Arc welding can be grouped into several categories such as Shielded Metal Arc Welding (SMAW), Gas Tungsten Arc Welding (GTAW), and Gas Metal Arc Welding (GMAW). This project uses GMAW or is also referred to as Metal Inert Gas welding (MIG) process. Gas metal arc welding is a process which incorporates the automatic feeding of a continuous, consumable electrode that is shielded by an externally supplied gas. While the equipment provides automatic self- regulation of the arc and deposition rate, the only manuals control required by the welder for semiautomatic operation are gun positioning, guidance and travel speed. The arc length and the current level are automatically maintained (Nadzam, 2014).

Modern, ultra-lightweight places demands on welding technology that simply cannot be met with traditional shielding gas welding processes. Variants of the robust arc welding


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process need to be developed which feed very little heat into the material but which still guarantee strong connections. S. F. Goecke states that the cold arc welding is a variant of MIG process that meets the demands. In this process, all inventions in the process flow are carried out directly in the power source without mechanical invention in the wire feed, which means that standard welding torches can be used and the process can also be used to produce excellent manual welding results. However, both GMAW and cold arc welding process can still lead to any defects and issues.

Two of the major problems of any welding process are residual stress and distortion (Colegrove, et al., 2009). Welding distortion, a result of the non-uniform expansion and contraction of weld metal and adjacent base metal during the heating and cooling cycle of the welding process, is a major concern during the fabrication of a welded structure (Yang, et al., 2014). In this research three welding parameters that influenced the distortion produced during welding are studied. The welding parameters are arc voltage, arc current and welding speed. These variables can be controlled through the welding equipment under the limitation of welding process and weld procedure (Waheed, et al., 2015). The influence of these parameters on weld distortion is studied by comparison of results between two welding processes which is GMAW and Cold Arc welding.

## 1.2 Problem Statement

Welding is more than a century old technology. In the early 19th century, electricity was developed and at the same time, welding technology was remarkably changed by the introduction of electric arc welding (Thwe, et al., 2009). Metal arc inert gas shielded welding, also known as MIG, MAGS or GMAW, was first in the USA in the mid-1940s. Since then, the process has been used extensively in a wide range of industries. Gas Metal Arc Welding (GMAW) machine as shown in is the most widely used arc welding process in industry. The benefits such as high production rates, high weld quality, ease of automation, and the ability to weld many metals make it attractive to manufacturer (Mathers, 2002).


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There are several method were used to assemble a car body such as laser weld, tailor welded blank, GMAW and spot weld. For this report, GMAW is chosen as the main research and experimental study (Mohamad, 2008). The process is used extensively for joining low carbon steel components for the bodies and chassis of automobiles, trucks, trailers, buses, mobile homes, motor homes and recreational vehicles, and appliances and many other products (Mohamad, 2008). However, there are always having issue regarding mechanical properties that would affect surface finish quality of the car body such as distortion, fracture and scratch. This problem will delay the time and production to recover it back.

Thus in order to avoid the time delay in production, welding distortion need to be eliminated by applying the processing method involves the use of a lower heat input such as Cold Arc. These methods generally have little effect on the magnitude of the tensile stress region which is typically around the yield value (Colegrove, et al., 2009). Therefore the result from Response Surface Method (RSM) will provide better analysis regarding the effect of welding parameters on welding distortion between both GMAW and Cold Arc process.

## 1.3 Objectives of the Study

The objectives of the study are as follows:

i. To investigate the effect of welding parameters with similar thickness of SPCC thin plate by different process to the welding distortion of the thin plate
ii. To propose optimization of parameter on the welded specimens by using GMAW and Cold Arc welding process
iii. To relate the effect of welding parameters to the welding distortion

## 1.4 Project Scope of Work

The scope of this study includes:


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i. Material used is SPCC Steel with different thickness.
ii. The sheet metal plate is joint by using GMAW and Cold Arc process by applying lap joint.
iii. Study of weld quality and distortion by using CNC Coordinate Measuring Machine (CMM)

## 1.5 Significance of Study

The purpose of this research is to determine the suitable welding process to reduce welding distortion. This study also evaluates the welding parameters that affect the most on the mechanical properties of the welded metal plate.

This study is done for the automotive industry. This is because automotive industry uses arc welding the most. In order to reduce CO2 emission, decreasing body weight is an urgent requirement in the automotive industry, and in this context, the need for application of thinner steel sheets of higher strength is increasing. In addition, besides reducing spatter, welding methods and consumables must be able to deal with gaps often seen with press-formed sheets (Kodama, et al., 2013).

The use of particularly cold arc welding power source for welding of body parts is increasing because of the ability of low heat-input welding and significantly low spatter (Kodama, et al., 2013). Thus this study gives benefit to automotive industry in comparing type of welding process which can reduce welding distortion.

## 1.6 Research Planning

The research planning is shown from the gantt chart below. The activities along with the weeks are represented in the gantt chart.


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Table 1.1 Gantt Chart of PSM I

| WEEK / TASK | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Find Supervisor** | ■ | | | | | | | | | | | | | |
| **Project title selection** | | ■ | | | | | | | | | | | | |
| **Discussion with supervisor** | | ■ | ■ | | | | | | | | | | | |
| **Writing proposal** | | | | | | | | | | | | | | |
| Chapter 1: Introduction | | | ■ | ■ | | | | | | | | | | |
| Chapter 2: Literature Review | | | | | ■ | ■ | ■ | | | | | | | |
| Chapter 3: Methodology | | | | | | | | ■ | ■ | | | | | |
| **Component survey** | | | | | | | | | | ■ | | | | |
| **Presentation preparation** | | | | | | | | | ■ | ■ | ■ | | | |
| **PSM I Poster presentation** | | | | | | | | | | | | ■ | | |
| **PSM I Report submission** | | | | | | | | | | | | | | ■ |

## 1.7 Summary

Arc welding touches almost every component of a vehicle. From the body-in-white to chassis components, powertrain, seating, exhaust, truck frames, axles and all types of steel and aluminium trailers, Gas Metal Arc Welding (GMAW) is an integral part of almost every part in the vehicle. Arc welding is widely used for chassis parts because of advantages such as the ease of continuous joining to secure high strength and rigidity of joints and wide freedom of joint shape to allow easy joining to pipes, brackets, or other accessories. Since chassis parts are composed of many components welded together, it is essential that weld joints are highly resistant to fatigue and corrosion (Kodama, et al., 2013).

New welding consumables aiming at suppressing spattering and improving gap weldability were developed. This paper reports the results of these studies and development activities. The other welding process that can be used in automotive industry is Cold Arc process which use low heat input to joint the thinnest sheet material. Therefore, welding distortion on the welded specimens will be observed between both processes.


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# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Welding History

Welding, a metal joining process can be traced back in history to the ancient times. In the Bronze Age, nearly 2000 years ago, circular boxes made of gold were welded in lap joint arrangement by applying pressure. Later on in the Iron Age, Egyptians started welding pieces of iron together. But welding as we know nowadays came into existence only in the 19th century (Islam, 2014).

According to Islam (2014), welding is a manufacturing process of creating a permanent joint obtained by the fusion of the surface of the parts to be joined together, with or without the application of pressure and a filler material. The materials to be joined may be similar or dissimilar to each other. The heat required for the fusion of the material may be obtained by burning of gas or by an electric arc. The latter method is more extensively used because of greater welding speed.

The weldability has been defined as the capacity of being welded into inseparable joints having specified properties such as definite weld strength proper structure. The weldability of any metal depends on five major factors. These are melting point, thermal conductivity, thermal expansion, surface condition, and change in microstructure (Saurabhjain, 2017).


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Figure 2.1 shows the overview of welding processes which is divided into several categories such as gas welding, resistance welding, arc welding, newer welding and solid state welding.

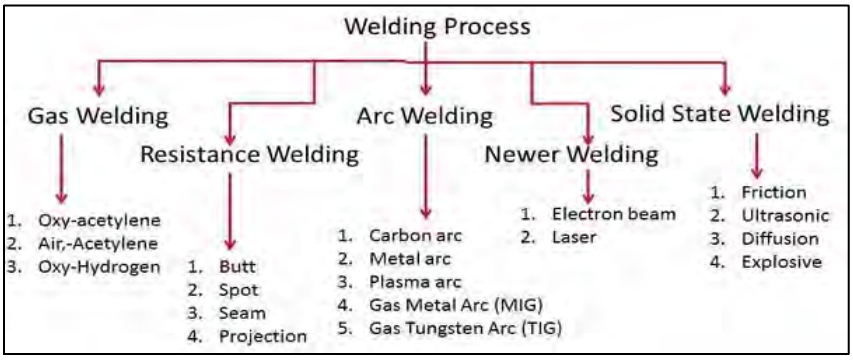


Figure 2.1 Welding Process Chart (Saurabhjain, 2017)

## 2.2 Gas Metal Arc Welding (GMAW)

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 alloy material range for GMAW includes carbon steel, stainless steel, aluminium, magnesium, copper, and nickel, silicon bronze and tubular metal-cored surfacing alloys. The GMAW process lends itself to semiautomatic, robotic automation and hard automation welding applications (Nadzam, 2014).

Figure 2.2 is a schematic diagram of robotic GMAW. It consists of four parts: the robotic system, the vision system, the weld power and the host computer. The robotic system is a six-degree FANUC industry robot. The weld power consists of a Lincoln AC welding machine and a wire feeder.


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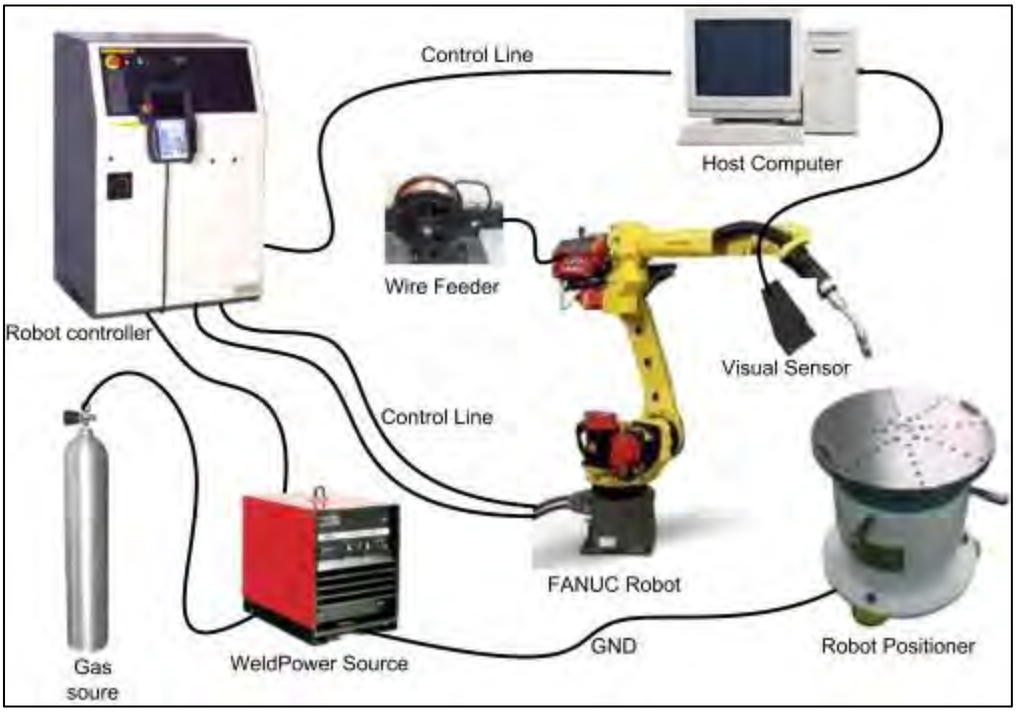


Figure 2.2 Robotic GMAW Systems (Xu, et al., 2015)

GMAW welding involves large number of interdependent variables that can affect product quality, productivity and cost effectiveness (Kim, et al., 2003). Many studies and researches have been made so far to determine the effect of welding parameters on weld properties and quality. Choi et al. (2005) researched on effect of current and voltage on strength of lap joints produced by CO2 welding process. Also, Kacar and Kokemli (2005) studied on influenced of controlled atmosphere on the GMAW arc weldment properties in low carbon steel. Other than that, A.R. Bahman and E. Alialhosseini (2010) investigate the arc voltage, welding current and welding speed effect on hardness, strength and UTS of weld metal of St 37 steel. However, nearly there exists little information about relationship between GMAW welding variables and mechanical properties of St 37 steel joints.

### 2.2.1 GMAW circuit

This is the basic equipment used for a typical GMAW, semiautomatic setup. Included are:

- A welding machine which provides welding power
- A wire feeder which controls the supply of wire to the gun


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