# TENSILE PROPERTIES ANALYSIS BY SIMULATION AND EXPERIMENT OF THIN SHEET PLATE WELDED BY GMAW

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

(Engineering Process) (Hons.)

by

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# DECLARATION

I hereby declare this report entitled “Tensile Properties Analysis by Simulation and Experiment of Thin Sheet Plate Welded by GMAW” is the results of my own research except as cited in reference.

Signature : …….....

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Date : 26 June 2019

# APPROVAL

This report is submitted in accordance to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment for the requirements for the degree of Bachelor Degree of Manufacturing Engineering (Engineering Process) (Hons.)

The members of the supervisory committee are as follows:

……..

(Associate Professor Dr. Nur Izan Syahriah binti Hussein) – Signature & Stamp

# ABSTRAK

Proses Metal Welding Arc Metal (GMAW) merupakan proses utama dalam proses kimpalan arka kerana ia memberikan produktiviti tinggi dan kualiti kimpalan yang baik. Tujuan kajian ini adalah untuk memahami bagaimana parameter kimpalan mempengaruhi sifat tegangan dan herotan kimpalan plat nipis dengan ketebalan berbeza oleh kimpalan Arc Cold. Arc Arc adalah proses pengelasan GMAW canggih yang menghasilkan sumber haba yang rendah sehingga sesuai untuk digunakan untuk plat keluli nipis. Proses kimpalan dilakukan dengan menggunakan wayar pengisi ER70S-6 dan menggunakan Robotic GMAW Kuka KRC4 dengan sumber kuasa EWM Cold Arc. Set parameter direka oleh Minitab. Gabungan voltan kimpalan, semasa kimpalan, dan kelajuan kimpalan yang boleh membentuk input haba proses itu digunakan dalam kajian ini. Kekuatan tegangan dan ledingan plat untuk dua ketebalan plat berbeza telah dikaji. Tambahan pula, data dianalisis dengan menggunakan Kaedah Response Surface untuk mendapatkan parameter kimpalan optimum yang dapat mengurangkan ledingan plat dan memaksimumkan kekuatan tegangan untuk pengelasan plat tipis oleh teknologi "ColdArc". Parameter optimum yang dicadangkan oleh kaedah RSM adalah 53.45 A untuk arus, 17.23 V bagi kelajuan voltan dan kimpalan 0.21 m / min dan haba yang disalurkan dikira. Kesimpulannya, peningkatan input haba menurun kekuatan tegangan sambungan kimpal. Untuk kadar ledingan plat, jika input haba meningkatkan ledingan meningkat. Selain itu, menggunakan perisian SolidWorks kekuatan tegangan gabungan dikimpal disimulasikan dan dibandingkan dengan hasil eksperimen.

# ABSTRACT

Gas Metal Arc Welding (GMAW) process is a leading development in arc welding process as it provides high productivity and good weld quality. The purpose of this study was to understand how the welding parameter effects the tensile properties and distortion of thin plate welding with dissimilar thickness by Cold Arc welding. Cold Arc is the advanced GMAW welding process which transmit low heat input thus it is suitable to be used for thin steel plate. The welding process performed by using ER70S-6 filler wire and use Robotic GMAW Kuka KRC4 with the power source EWM Cold Arc. The set of parameters is designed by Minitab. The combinations of welding voltage, welding current, and welding speed in which can form the heat input of the process were employed in this study. The tensile strength and distortion of the lap joint with a dissimilar thickness were studied. Furthermore, data was analysed by using Response Surface Methodology to propose optimum welding parameter that can minimize distortion and maximise tensile strength for thin plate welding by "ColdArc" technology. The optimum parameter proposed by RSM method was 53.45 A for current, 17.23 V for voltage and welding speed of 0.21 m/min and heat input is calculated. As a result, rise in heat input decreased tensile strength of the weld joint. For bending distortion, as the heat input increase the distortion increased. Also, using SolidWorks software the tensile strength of welded joined was simulated and compared with experimental results.

# DEDICATION

Only

My beloved father, Zulkefle Husain

My loving mother, Munira Hassim

The reason of what I become today

Thank You

For giving me moral support, encouragement and understandings

Love you

With all my heart

Always Have, Always Will

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# LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| ASTM | - | American Society of Testing and Material |
| CMT | - | Cold Metal Transfer |
| $CO_2$ | - | Carbon Dioxide |
| DOE | - | Design of Experiment |
| GMAW | - | Gas Metal Arc Welding |
| GTAW | - | Gas Tungsten Arc Welding |
| HAZ | - | Heat Affected Zone |
| MAG | - | Metal Active Gas |
| MIG | - | Metal Inert Gas |
| SAW | - | Submerged Arc Welding |
| SMAW | - | Shielded Metal Arc Welding |
| RSM | - | Response Surface Methodology |

# CHAPTER 1

# INTRODUCTION

This section clarifies the background, objective, problem statement, scope of the final year project and followed by the organization of the final year report. The background discusses about the overview of the welding process and the limitation. Next, the objective indicates about the mission needed to be achieved for this project. Lastly, the scope mentions about what is supposed to be accomplish in this project.

## 1.1 Background of Study

Metal industries use a variety of techniques to combine various components and the joining techniques can be perpetual or impermanent depending on the product type and design. The last techniques use parts such as fasteners, screws and bolts, although they are temporary attached unlike welding which provide permanent joining. Among the joining technique that usually used in metal industries, welding stands out the most either in job shop or in fully-automated-controlled factories (Kah & Martikainen, 2012). Improved structural performance, weight reduction and cost saving are one of advantages that welding can provide over mechanical joining method (Deng & Murakawa, 2008).

Welding is a processes in which materials of the same basic type or class are combined and converted into one by forming primary chemical bonds in combination with heat and pressure (Messler, 2008). A group of welding process which implement concept of generation of electric arc by electricity to melt the filler wire and form welding pool for joining components is known as arc welding (Kah et al, 2012). Arc welding occupies the most important position in the fusion welding process group and is an indispensable technology for the construction of steel framed buildings, shipbuilding, motor vehicle manufacturing and other industries due to its flexibility and cost-effectiveness.

Arc welding can be grouped into several categories such as Gas Tungsten Arc Welding (GTAW), Gas Metal Arc Welding (GMAW) and Shielded Metal Arc Welding (SMAW). This project uses GMAW or is also referred to as Metal Inert Gas welding (MIG) consist mechanism that uses a continuous consumable solid wire as both for electrode and filler metal with aided of an inert shielding gas to protect the arc and the welding pool (Lathabai, 2011) . The welding parameters that are controlled to produce acceptable welds are arc current, arc voltage, wire feed speed, electrode travel speed, current density and preheat temperature (Mallick, 2010).

There are several advantages of GMAW. Firstly, GMAW is the most widely process used since the process equipment is low, it comes with low cost consumable, it offers high deposition rates as compared to stick welding and it has high electrode efficiencies. Next, it has low hydrogen deposits, comes with low levels of spatter when the right mode of metal transfer is selected. Besides, due to bare electrode wire aided with inert shielding gas it does not require manual grinding and cleaning of slag. Furthermore, GMAW is the electric arc process where the spool of continuously fed wire been used. It also able to join the long stretches of metal without discontinuing. Other than that, all metals can be weld by using GMAW process by simply exchanging the filler wire.

In recent years, it is a trend for automotive manufacturers to use thin plates for constructing cars' body. Thin plates are popular among the manufacturers because it will minimize transports' weight and reduce the fabrication work. When the weight car body reduced, the fuel cost will be reducing simultaneously. According to Kodama (2013), in order to reduce $CO_2$ emission, decreasing body weight is an urgent requirement in the automotive industry thus the demand of using thinner steel sheets of higher strength is

increasing. However, the increased of thin plate will cause the increased of distortion. This is because thinner material is more susceptible, as it has less stiffness (Beardsley, 2008). Deng & Murakawa (2008) also stated buckling distortion is a major problem when welding is involved to join thin plate parts.

Residual stress and distortion are the serious problem that often occurs in any welding process (Colegrove et al 2009). Occurrence of welding distortion commonly cause by uniform expansion and contraction of welded metal and adjacent base metal during the heating and cooling cycle of the welding process which become is a major limitation in welded structure. (Yang et al, 2014). This welding deformation not only has a negative effect on the production accuracy, but also significantly reduces quality and increases manufacturing costs (Liang & Murakawa, 2012).

Cold arc welding process is the advanced of GMAW and these two welding processes implement short arc mechanism. Cold arc welding process involving a low heat input process which cause reduction of distortion and spatter. Compared to other welding process such GMAW, Cold Arc only produced low heat input thus it can be used for joining thinnest sheets from 0.3 mm thickness. In this research three welding parameters that influenced the distortion produced during welding are studied which are welding speed, arc voltage and arc current.

## 1.2 Problem Statement

Over a century welding have been introduced to the world. Welding is a process in which two or more parts are permanently joined by an appropriate application of heat and/or pressure on their touching surfaces and a filler material is often added to make coalescence easier. Welding technology was significantly changed by the introduction of electric arc welding when the electricity first introduced to the world. Welding played important roles in development and modernization of nations (Thwe, et al., 2009).

The welding parameters that are controlled to produce acceptable welds are arc current, arc voltage, wire feed speed, electrode travel speed, current density and preheat

temperature. GMAW provides benefits that make it more attractive to manufacturer such as high production rates, high weld quality, ease of automation, and the ability to weld many metals (Mathers, 2002).

Despite the offer of many advantages, application of GMAW technology is still limited to the thin plate steel. There is no suitable parameter found that can be used to weld thin plate steel without having complication. The optimum set of parameters to weld thin steel plate is important as usage of thin plate steel keeps increasing year by year as manufacture began to realise the benefit it can offers.

Welding technology in the automotive industry is widely used where the processes such as laser welding, tailor welded blank, GMAW and spot welding are commonly used in the assembly of the car body. In recent years, to come out with the design that can reduce weight and contribute to fuel consumption the automotive industry introduce design with thin plate steel with high strength (Huang et al, 2003). However, the buckling distortion appears to be a serious problem with welding technology for assembling thin plates. Buckling distortion causes loss of structural integrity and control of dimensions and increases manufacturing costs due to poor component fitting. Correcting the distortion takes time and also degrades to the weldment quality (Deng & Murakawa, 2011). As a result of this problem, a new welding process must be introduced worldwide, since thin plates cannot be welded using normal GMAW processes due to high heat input.

In order to avoid production time delays, the welding distortion must be eliminated by using the different method of welding, using a lower heat input such as Cold Arc. It is also critical measures to predict accurately the welding tensile strength to achieve high productivity of the thin plate welded structure as there will not problems arises during consumption phase (Deng & Murakawa, 2011).

## 1. 3 Objective

Objectives of this study are:

i. To study the effect of welding parameter to the tensile strength and distortion of SPCC thin steel plate of different thickness.

ii. To propose the optimum set of welding parameter for thin plate steel using GMAW that enable to minimise distortion and maximise tensile strength.

iii. To compare result of ultimate tensile strength from simulation and experimental.

## 1.4 Scopes

In this study, the scope included are the material, welding parameter, welding robot and power source study of weld quality and distortion and tensile testing. The raw material used was SPCC Steel with different thickness which are 0.8 mm and 1.0 mm. The dimension of plates used as sample were 80mm x 200mm. For the welding parameter in this study were current (32 – 48 A), voltage (6.5 -14.50 V) and welding travel speed (0.35 – 0.75 m/min).The welding robot used was GMAW Kuka KRC4 with EWM Cold Arc as the power source. The sheet metal plate was joint by using Cold Arc process by applying lap joint. The study of weld tensile strength was done using Static Structural by SolidWorks software. Tensile testing was performed using Universal Testing Machine (UTM) to determine the tensile properties of the sample.

## 1.5 Significance of study

The aim of this research is to determine the optimum welding parameter to reduce welding distortion and investigate the welding parameter that affect the tensile properties of the welded metal plate.

This study focuses on the automotive industry as arc welding usually being used to assembly the cars' parts. In order to reduce $CO_2$ 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 (Kodama, et al., 2013). By introduce thin plate steel with high strength in automotive industry it provides weight reduction and fuel saving (Deng, 2008). A change in the weight of an automobile can affect the automobile's average fuel consumption (Berjoza & Jurgena, 2017).

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 (Kondo, 2010). Cold Arc with ability of low heat-input welding and significantly low spatter is chosen to be best choice in joining thin plate. Cold Arc is ideal to be used in various welding task especially in the field where normal short arc is no longer suitable such as construction of vehicles (Rosado et al, 2008). Therefore, this study gives benefit to automotive industry in comparing type of welding process which can reduce welding distortion.

## 1.6 Organization of Report

Chapter 1: Introduction

This chapter consists of general information of welding and the study of this thesis. This chapter is divided into five subtopics which are the background, problem statement, objectives, scope, the significance of the study the organisation of the report and research planning.

The background provides clear information of this study which will give the reader the necessary information of what the study is about. In this chapter also, the problems that arise will be stated also the reason on why this study should be done and what the objectives that need to be achieved in the end. In this chapter the areas and limitation of the study is also stated.

Chapter 2: Literature review

This chapter discussed on the theories, ideologies and the purposes of the topics. This chapter need ample search of journals, books, articles, research papers and etc in order to get plentiful knowledge and study materials to ensure the studies done is relevant. This chapter is provided to the introduction, body and conclusions. The introductions will give a quick review on the topic of the literature review, the body parts contain the discussion of the study sources and the conclusion is discuss on what has been achieves from doing this literature review.

Chapter 3: Methodology

Methodology is the method on how the study is conducted. It presents the sequential, methodical and the organized procedure on the study. In this chapter compose of the independent, dependent and controlled variables of the experiment design. It provides detail information on how the experiment is conducted and the checklist before conducting the experiment.

Chapter 4: Result and Discussion

Result and discussion composed of results that have been obtained experimentally and discussion regarding the result. This chapter include data in forms of figure, graph and tables. All the justification regarding the data collected is included in this chapter.

Chapter 5: Conclusion and Recommendations

Conclusion and Recommendation is an overview of the overall project that have been done. This chapter summarize all the objectives of the study that have been achieved. Recommendation also is included in this chapter for further improvement. Also, sustainability and complexity of the study also being mentioned in this chapter.