WELDING DISTORTION ANALYSIS USING FEM AND EXPERIMENT

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

by

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Hons). The member of the supervisory committee are as follow:

……………………..................................

(PROF.MADYA DR NUR IZAN SYAHRIAH BT HUSSEIN)

……………………….................

(EN MOHAMAD NIZAM BIN AYOF)

ABSTRAK

Proses kimpalan adalah proses penyambungan logam yang cekap yang dicapai oleh kimpalan arc logam gas (GMAW). Pemanasan setempat semasa proses kimpalan boleh menyebabkan gangguan dan plat yang dikimpal. Anggaran magnitud dan pengagihan penyelewengan adalah penting untuk mengekalkan kualiti produk. Kajian kaedah unsur terhingga untuk menyiasat proses kimpalan arka logam gas (GMAW) disebabkan kelakuan ubah bentuk keluli plat keluli sejuk yang dilancarkan (SPCC) pada lapisan lap plat tipis. Kajian model unsur terhingga thermo-mekanikal dua dimensi digunakan untuk menganalisis dan menilai kelakuan distorsi di sendi lap. Hasil penyimpangan analisis elemen terhingga dibandingkan dengan data eksperimen untuk mengesahkan ketepatan kaedah.

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ABSTRACT

Welding process is an efficient joining process of metals that achieved by gas metal arc welding (GMAW) process. Localized heating during welding process can result distortion and in the welded plate. The estimate the magnitude and distribution of distortion is important to maintain the quality of products. Finite element method study to investigate the gas metal arc welding (GMAW) process induced distortions behavior of steel plate cold rolled (SPCC) material in lap joint of thin plate. A three-dimensional, two-step thermo-mechanical finite element model study apply to analyze and evaluate distortion behavior in lap joint. The result of distortion of finite element analysis was compare with experimental data to confirm the accuracy of the method.

DEDICATION

Only

my beloved father, Zainol Bin Noordin

my appreciated mother, Zamilah Binti Jusoh

my adored sister, Nor Zafirah

for giving me moral support, encouragement and understandings

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LIST OF ABBREVIATIONS

FEM	-	Finite Element Modelling
SPCC	-	Steel Plate Cold Rolled
GMAW	-	Gas Metal Arc Welding
DOE	-	Design of Experiments
RSM	-	Response Surface Methodology
AWS	-	American Welding Society
CMM	-	Coordinate Measuring Machine
FZ	-	Fusion Zone
HAZ	-	Heat Affected Zone
ANOVA	-	Analysis of Variance

LIST OF SYMBOLS

cm	-	Centimetre
m	-	Metre
%	-	Percent
g/cm3	-	Grams per centimeter cube
wt. %	-	Weight percent
mm	-	Millimetre
MPa	-	Mega Pascal
GPa	-	Giga Pascal
°C	-	Degree Celsius
TPa	-	Tera Pascal
W/mK	-	Watt per metre per Kelvin
K	-	Kelvin
kg/cm^3	-	Kilogram centimetre cube
kg	-	Kilograms
mm/min.	-	Millimetre per minute
A	-	Ampere
V	-	Volts
mm/s	-	Milimetre per second
g/ cm^3	-	Gram per centimetre cube
W/m°C	-	Watt per metre Celsius
W/mm°C	-	Watt per milimetre Celsius
KJ/mm	-	Kilojoules per milimetre
W	-	Watt
µm/m°C	-	Micrometer per meter Celsius
W/mm^2	-	Watt per milimetre square
°C	-	Celcius

CHAPTER 1

INTRODUCTION

This chapter describes introduction title of project and concisely explain the prediction distortion of welding using Finite Element Analysis. In addition, the planning of completing final year project was discussing. Scope and importance of this project also cover in this chapter.

1.1 Background

The manufacturing technology advance provide the productive tools that enable manufacturers to make products have better quality and complexity. In manufacturing production, the industrial robotics was common applied in welding industry to manufacturer products with better quality and products faster. Robotic welding has the good advantages with consistent cycles times, faster, no break in production and better weld quality that innovate to advance of automotive application and welding industrial workplace. Robotic welding system can achieve goals in remaining competitive which continually for ways to increase throughput and minimize defects.

However, according to (Islam *et al.*, 2015) welding induced permanent deformation like formation of distortion of welded product. Hence, the control of weld distortion is a vital task in welding manufacturing. Distortion can give negative impact quality on welded product such as on dimensional accuracy and joint strength. Hence, the weld treatments to achieve preferred level of dimensional accuracy of the welded product costly and time consuming.

Several parameters like heat input, welding sequences, condition and joint details in welding process contribute to the deformation of distortion on welded products. All factors of welding variables have to control for eliminate the condition promote distortion. Thus, Finite Element technique is the powerful tool to predict the distortion behavior of structures during welding process (Bhatti *et al.*, 2015). FEM for welding simulation was successfully used by many researches for prediction distortion of welded product (Islam *et al.*, 2015).

1.2 Problem Statement

Welding process is extensively used joining process in several manufacturing industries especially automotive, aerospace and shipbuilding industries (Review, 2009). Welding techniques widely used in joining component body automobile together (Devarasiddappa, 2014). Automotive industry frequently uses the welding field in reconditioning method for parts due to its advantages such as reduction of productions costs and increase in the durability of the hard faced parts. Thus, welding process have significant impact on achieving production goals and maintaining efficiency.

In spite of their advantages, arc welding processes effect highly non uniform heating of the parts being joined resulting distortion (Rethmeier, 2011). Producing good welded product continually challenged nowadays to provide good quality of welding. The changes in physical of fabricated structure or component after welding process is called welding distortion and become major problem in assembling industries mainly in the automotive industry. The welding deformation can influence the quality of welding and become the most important factor. The welding distortion can cause the cracks, machining precision and dimensional stability of structures that affect the quality of products (Chivu *et al.*, 2015). Thus, rework need to be done to remove the distortion but weld treatment required expensive cost and time consuming to avoid the inaccuracy level of dimension of the welded products (Islam *et al.*, 2015).

The prediction of welding deformation cannot be done depending only experimental data due several factors that involved in welding process especially for a large structure.

Therefore, with the advance of the computer skill, the FEM become trends in the recent years to prediction distortion. Minimize or eliminated the time lost with preliminary test for the approval of welds become current trend in the fields of welded products respectively of welding technologies (Chivu *et al.*, 2015). Determining optimal welding parameter will result in good condition of welded structure (Islam *et al.*, 2015). Perfect and good joint on welded structure impossible to achieve without an optimal welding structure.

1.3 Objectives of Study

The objectives of this study are:

i. To develop Finite Element Modelling (FEM) as to predict distortion.
ii. To analyze the effect of welding parameters towards distortion behavior using simulation.
iii. To get optimum parameter promote less distortion.

1.4 Scope of Study

In this researches project, simulation study is conducted using FEM software followed by experimental analysis to validate the simulation outcome. The FE software used by ANSYS software for simulation study. For experimental investigation, the robot welding model is KUKA Robot select to perform gas metal arc welding task. Material SPCC will be used for welding parameter optimization. The welding parameters that selected are welding voltage, welding current and welding speed. The type joint is lap joint to perform this welding task.

1.5 Importance of Study

According to Islam *et al.*, 2015 says that to eliminate the condition promote distortion, the welding variable have to control better. The amount of experiment trials is often essential in order to get more vision into the welding problem. Welding process as a fabrication technique poses difficult to the design and manufacturing community. Thus, the numerous factors that affect the quality of products while welding process required to be minimized. Many times of experiment and numerical analysis have been conducted in past decades for prediction welding deformation (Deng and Murakawa, 2008).

The automotive industry normally used thin plate parts for assembled by welding process. However, the thin plate has narrow literature in describing of the prediction and measurement of welding deformation (Rethmeier, 2011). Then, computational modeling in finite element always used as suggestion in the situation of welded structures and applied at design stage. These computational modelling can be related with the dissimilar design configurations, alternative welding processes, material thickness and fabrication sequences that can be discovered in a fundamental manufacturing environment. Therefore, it can propose the avoiding trial and error at the manufacturing stage. The exponential growth of capabilities of computers and the improvements in numerical algorithms and geometric modelling, development of computational models, as an alternative to experiments, has become popular in solving many industrial problems such as automotive industry.

The development of computational models will reduce the number and the cost of experiments and time consuming. Finite element models are generally capable of incorporating almost all the characteristics of the materials to be welded. Finite element also can incorporate with the temperature dependency of the properties of the materials, complex shapes, dissimilar materials, modeling of filler wire and distributed affecting heat source. The most commonly welding process used in automotive industry are spot welding and metal inert gas that require expensive cost to give best quality of welded product (Devarasiddappa, 2014) . Thus, propose this finite element method in finding the optimum parameter of welding process in result minimum deformation.

1.6 Research Planning

Project planning is important in study to make sure objective of study research can be achieved with time prescribed. Research planning also can ensure the project was carries out is consistent. Thus, Gantt chart method is used to illustrate the progress of project implementation in this research. Gantt chart for PSM 1 and 2 was shows in appendix A and B.

1.7 Organization of Report

This researches report begins with Chapter 1 as Introduction and this chapter describes the background, problem statement and scopes of this project. Chapter 2 Literature Review which presents literature researches of researches and summarizing points. Then follow with Chapter 3 Methodology presents the methodology while conduct the overall final project including the process flow of this project. Chapter 4 Finite Element Modelling deals with the development of a three-dimensional finite element modelling to predict distortion in lap joint. Chapter 5 Discussion covers the experimental results of distortion of lap joints and comparison with finite element modelling with same parameter. Chapter 6 covers the overall conclusion of the research work and recommendation.

CHAPTER 2

LITERATURE REVIEW

This chapter review deliberating point, idea and knowledge that have been studied by other researches. The important point of related journal will be summarizing in this chapter for this project researches.

2.1 Introduction

In industries, welding is the most popular method to obtain permanent joint of two metal that used material either metal or non-metal. Moreover, welding is extensively used in many active applications especially in constructions and automotive industries. The performance of these industries as respects of productivity, meeting delivery schedule and product quality depends on the structural designs and welding technology. Although having all advantages in welding operation, process of welding also leads to disadvantages like distortion in weld structures and residual stresses because welding process depend on an strongly localized heat input in case thin plate (Review, 2009). Welding shows a very important part as far as productivity and quality of end product. Thus, having all these disadvantage will make the performance of industries disturbance. The distortion can affect the changes of shape in welding structure and residual stresses affecting on fatigue strength, corrosion strength and stability (Khurram and Shehzad, 2013).

Among the major area of application, welding widely used in automotive industry. The endless demand in better-quality material requirement for automotive applications requires the advanced joining technique (Devarasiddappa, 2014). The most normally use welding methods for automotive application are gas metal arc welding (GMAW), resistance spot welding (RSW), friction welding (FS), laser beam welding (LSM) and plasma arc welding(PAW). The distortion and residual stress normally occur during and after the welding process. Thus, the controls of variable during welding process is very important to avoid critical negative impact. In order to decrease these negative impact of welding, many procedures already done but are often coupled with highly cost extensive experiment (Rethmeier, 2011). Therefore, prediction and analysis of welding deformation are key factors in industrial context in order to increase the productivity and decrease the cost (Ghanadi, 2013).

2.2 Finite Element Method

Finite element analysis is a technique for numerical solution of field problems (Heinze *et al.*, 2012). A field problem involves the determination of three-dimensional distribution of one or more dependent variables as parameters (Heinze *et al.*, 2012). Field problem is defined as differential equations or integral expression in mathematically. The elements are coupled at points called "nodes" and the assembly of elements is known as a finite element model or structure. The specific arrangement of elements is known as a mesh. Finite element modelling preparing a computational model for analyses the process (Hashemzadeh *et al.*, 2017). Simulation involves prediction of the output of the computational model such as prediction of distortion and residual stress in welding process (Deng and Murakawa, 2008). Welding simulation generally consists of transient thermal simulation to predict distribution of temperature histories and static structural simulation to predict the distortion in the welded structures.

2.3 Arc Welding

Welding usually includes the application or development of localized heat close to the intended joint. The arc welding applies in varied group of welding methods that use an electric arc as the source of heat to melt and join the metals. Raj *et al.*, (2017) claimed that the electric arc could be stuck between two carbon electrodes. Struck of arc between metal rod and workpiece will resulting both rod and workpiece surface melt to form a weld pool

(Raj *et al.*, 2017). The electrode can be a consumable wire or rod or a no consumable carbon or tungsten rod which transfers the welding current. Arc welding is known as complex operation involving extremely high temperatures that produce distortion and residual stress (Raj *et al.*, 2017).

2.3.1 Gas Metal Arc Welding (GMAW)

Gas metal arc welding (GMAW) is a welding process used an electric arc forms between a consumable wire electrode and the workpiece which give heats to the workpiece causing them to melt and joint as shown in Figure 2.1. Sometimes GMAW stated by its subtypes of metal inert gas and metal active gas. MIG welding states use an inert gas while MAG state use active gas. The wire electrode, a shielding gas feeds over the welding gun that to prevent the atmosphere contaminating the weld. The process can be automatic or semi-automatic. Furthermore, the wire is used as electrode in gas metal arc welding. (Raj *et al.*, 2017) claims that the electric arc could be stuck between two carbon electrodes which according to (Sun and Wu, 2001). The electrode continuously melts and fed to maintain arc welding. Arc flow and the arc connection at the anode wire have important impact on the droplet formation and the heat transfer. Welding heat transfer can be effect on the welding thermal cycle (Sun and Wu, 2001).

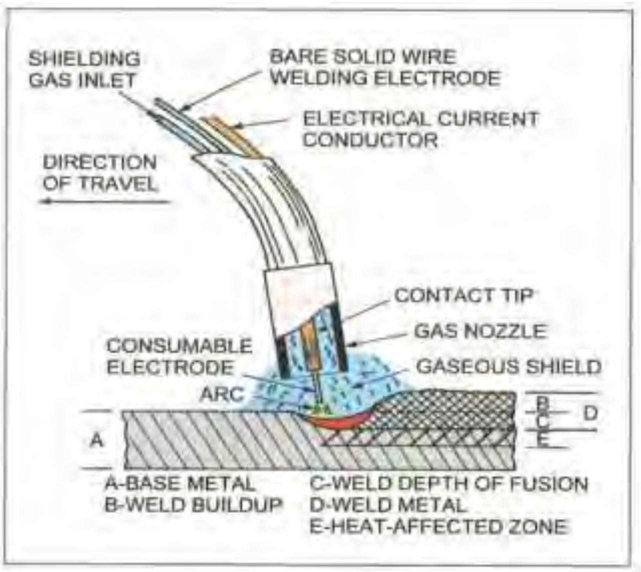

Figure 2.1: GMAW Process (Kaputsa,2014)