Faculty of Manufacturing Engineering

OPTIMIZATION OF WELDING PARAMETERS ON MECHANICAL PROPERTIES OF ALUMINIUM ALLOY 7075

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A thesis submitted in fulfilment of the requirements for the degree of Master of Manufacturing Engineering (Quality System Engineering)

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DECLARATION

I declare that this thesis entitled "Optimization of Welding Parameters on Mechanical Properties of Aluminium Alloy 7075" 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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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 fulfillment of Master of Manufacturing Engineering (Quality System Engineering).

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DEDICATION

In the name of Allah, The Most Beneficient, The most Merciful

Every challenging work needs self-efforts as well as guidance of elders especially those who were very close to our heart.

My humble effort I dedicate to my sweet and loving

Papa & Mama,

Yomli Bin Ramaini & Adlinda Binti Bahtiar

Whose affection, love, encouragement and prays of day and night make me able to have such success and honour.

Along with helpful and supportive

Beloved friend

Syarool Anies Bin Sazali

ABSTRACT

This project is to study the effects of welding parameters for aluminium alloy 7075 towards the material characterization. The welding process used is Gas Metal Arc Welding (GMAW). The raw material used in this project is Aluminium Alloy (AA) 7075 and welded by using the KUKA robotic welding machine. The AA7075 was butt jointed with constant bevel angle which is 60°. There are three most important parameters of GMAW process that have been identified, which are current (A), voltage (V) and travel speed (S). The experiment is designed by using Design of Experiment (DOE) which is Response Surface Methodology (RSM) method. RSM method and Analysis of Variance (ANOVA) are used to optimize and validate the welding parameters. After that, the workpiece was cut into 11 samples with required dimensions in a dumbbell shape specimen by using wire EDM machine. Then the tensile test is conducted to observe the ultimate tensile strength (UTS), tensile modulus and also percentage elongation. The highest value of UTS obtained is 185.989 N/mm^2. While the highest value of tensile modulus obtained is 20.44 N/mm^2. For percentage elongation, the highest value obtained is 6%. Next, the Vickers hardness test is conducted to observe the hardness value which is measured to organize the revolution of mechanical property of weldment area. The highest value of hardness obtained is 89.3 HV. In addition, the microstructure of the sample is observed by using an optical microscope. It is to observe the length of the Heat Affected Zone (HAZ), grain size of weldment area and base metal. Multi-objective result shows that welding current at 143.7855 A and welding speed at 0.5329 m/min which 183.2128 MPa for UTS, 20.4992 MPa for tensile modulus, 6.3539% for percentage elongation and 88.7604 HV for hardness. Multi objective result shows that output of responses become slightly lower than single objective. This due to the multi-objective takes consideration all target.

ABSTRAK

Projek ini adalah untuk mengkaji kesan parameter kimpalan untuk aloi aluminium 7075 ke arah pencirian material. Proses kimpalan yang digunakan ialah kimpalan arka logam gas (GMAW). Bahan mentah yang digunakan dalam projek ini ialah aloi alumina 7075 (AA 7075) dan dikimpal dengan menggunakan mesin kimpalan robot KUKA. AA 7075 adalah punggung yang disambungkan dengan sudut serong yang berterusan iaitu 60 °. Terdapat tiga parameter yang paling penting dalam proses GMAW itu telah dikenalpasti, iaitu arus elektrik (A), voltan (V) dan perjalanan kelajuan (S). Eksperimen ini direka·bentuk dengan menggunakan Reka Bentuk Eksperimen (DOE) yang merupakan metodologi permukaan tindak balas (RSM). Kaedah RSM dan analisis perbedaan (ANOVA) digunakan untuk mengoptimumkan dan mengesahkan parameter kimpalan. Selepas itu bahawa, bahan kerja dipotong menjadi 11 sampel dengan keperluan dimensi dalam spesimen bentuk dumbbell dengan menggunakan dawai EDM mesin. Kemudian ujian tegangan dijalankan untuk memerhatikan muktamad kekuatan tegangan (UTS), modulus tegangan dan juga pemanjangan peratusan. Nilai tertinggi UTS yang diperoleh adalah 185.989 N/mm. Manakala nilai tertinggi yang diperoleh untuk modulus tegangan adalah 20.44 N/mm^2. Pemanjangan peratusan yang tertinggi adalah 6%. Seterusnya, ujian kekerasan Vickers dijalankan untuk memerhatikan nilai kekerasan yang diukur untuk menganjurkan revolusi harta mekanik kawasan kimpalan. Nilai tertinggi yang diperoleh setelah melakukan ujian kekerasan Vickers adalah 89.3 HV. Di samping itu, struktur mikro sampel diperhatikan dengan menggunakan optic mikroskop. Ia adalah untuk memerhatikan panjang zon yang terkena haba (HAZ), saiz bijian kawasan kimpalan dan logam asas. Keputusan pelbagai objektif menunjukkan bahawa arus kimpalan pada kelajuan 143.7855 A dan kimpalan pada 0.5329 m / min yang 183.2128 MPa untuk UTS, 20.4992 MPa untuk modulus tegangan, 6.3539% untuk perpanjangan peratusan dan 88.7604 HV untuk kekerasan. Keputusan pelbagai objektif menunjukkan bahawa output respons menjadi sedikit lebih rendah daripada objektif tunggal. Ini kerana multi-objektif mengambil kira semua sasaran.

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LIST OF ABBREVIATIONS

UTeM	-	Universiti Teknikal Malaysia Melaka
GMAW	-	Gas Metal Arc Welding
DOE	-	Design of Experiment
AA7075	-	Aluminium Alloy 7075
UTS	-	Ultimate Tensile Strength
ANOVA	-	Analysis of Variance
UTM	-	Ultimate Tensile Machine
WEDM	-	Wire Electrical Discharge Machining
RSM	-	Response Surface Methodology
CCD	-	Central Composite Design

CHAPTER 1

INTRODUCTION

This section clarifies the background, objective, statement of problem, scope of the master project and tracked by the organisation of the report. The background deliberates about the general idea of the process of gas metal arc welding (GMAW) and the parameters involved in the process. Afterward, the objective specifies about the task desired to be attained for this project. Last of all, the scope declares about what is invented to be accomplished in this project.

1.0 Research background

Gas metal arc welding (GMAW) is a welding process which the metal been joined by heating the metals up until it reach the melting point by way of an electric arc that forms in the middle of a usable wire electrode and the workpiece metals. GMAW process can be done in semiautomatic welding, machine welding and automatic welding. In semiautomatic welding, the wire feeding electrode is controlled through the tools, while the movement of welding gun is controlled by hand. In machine welding, gun that attached to a manipulator which is not hand-held is used. The controls need to constantly set and adjust. In automatic welding, the tools that welds devoid of persistent adjusting of controls by user is used. Automatic detecting devices control the precise gun alignment in a weld joint on the same equipment.

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, it does not require manual grinding and scrubbing of slag as the bare electrode wire plus shielding gases remove slag on weld bead. Furthermore, GMAW is the electric arc process where the spool of constantly fed wire been used. That one also able to join the extended elasticities of metal devoid of discontinuing. Other than that, all metals can be weld by using GMAW process by simply exchanging the filler wire.

In the manufacturing, GMAW is the utmost technique which generally utilized intended for welding ferrous and nonferrous materials. It is a melting welding technique applied in mutually industrial and repairing activities. GMAW has different points of interest over other melting welding techniques. According to (Suhail, 2014), high welding speed, huge metal removal, and spatter unrestricted welding at allowable expense than further welding methods in linking comparable and unrelated metals are some of its points of interest. Furthermore, it is pertinent aimed at a widespread assortment of marketable metals and alloys, for instance, carbon steel, stainless steel, copper and aluminum.

The applications of GMAW process for aluminium alloy usually found in aircraft and aerospace, marine fittings, bicycle frames and components, fly fishing reels, brake components, driveshafts, etc (Sivashanmugam *et al.*, 2009). GMAW process is developed to weld aluminium and aluminium alloy by using an inert shielding gas. Moreover, it is an automated technique and allows robot use. With the intention of acquire decent quality of weld, the selection of process parameters play an important key in research. Thus, it is compulsory to select the process parameters more precisely.

Mechanical properties are the properties which involved in reacting to an applied load. Mechanical properties for instance tensile strength, hardness and structure boundary are the most common properties measured especially in the GMAW process. Tensile test is the ultimate mechanical test which can be accomplished on material to measure the strength of a material. Ultimate tensile strength, yield strength and percentage elongation are part of material specification obtained in a tensile test.

Hardness is the resistance of material towards permanent deformation once load is applied for instance indentation, stiffness, abrasion and scratch. When the hardness of the metal is greater, it will result in higher resistance to deformation (Ibrahim *et al.*, 2012a). There are three scales of hardness measurement which are macro, micro and nano depending on the forces applied. Macro hardness can be tested by using Rockwell, Brinell, and Vicker Hardness Test.

Grains and grain boundaries are a small group of atoms which started to assemble into a crystalline form once the metal that has been cooled is reached its freezing point. The small crystals distributed all the way through the body of liquid where it's been oriented in all directions and by way of solidification endures, crystal that formed from the surrounding liquid is increasing. It is in the form of treelike structure or dendrites. (Avinash *et al.*, 2014), the solidified grain size and structure are affected by temperature and cooling rate.

Therefore, this project investigates about the influence of welding parameters for instance Voltage (V), Current (A), and travel speed (m/s) and the output responses which covered in this project are tensile strength, tensile modulus, percentage elongation, hardness at the welded area as well as the microstructure of the base metal and weldment area.

1.2 Problem statement

The entire research, GMAW process parameters play an important factor since it contribute to the good quality of product, the effectiveness of the process and data can be analysed precisely. To acquire a decent welded joint with required quality in strength by controlling the procedure input parameter is the most basic issue encountered by company. In order to give electric flow to soften both the terminal and an appropriate measure of base metal, the procedure requires adequate control parameter.

According to (Ibrahim *et al.*, 2012a) there are a lot of parameters that can greatly influence the mechanical properties of welded aluminium alloy can be used, but the most important parameters must be identified to avoid higher material lost due to trial and error in order to get the suitable one. Thus, DOE is used in this research to reduce trial and error and to discover the optimal quality of welded joint. Besides, this research investigate whether these selected parameters are able to enhance the quality of welding or vice versa.

1.3 Objectives

The main objective of this project is to examine the influence of welding parameter on material characterization of welded Aluminium Alloy 7075. In the direction to accomplish the foremost objective, the three sub-objectives are outline:

(a) To study the suitable factors of welding such as welding current and welding speed to enhance the good quality of weld.

(b) To investigate the ultimate tensile strength, tensile modulus, percentage elongation and hardness of weldment area.

(c) To optimize and validate the welding parameters by using response surface method (RSM) and analysis of variance (ANOVA).

1.4 Scopes of the research

This project was conducted at the laboratory in Universiti Teknikal Malaysia Melaka (UTeM) by using KUKA welding machine. KUKA welding machine been used because of its exact positioning accuracy during the operation of welding. This project was carried out by measuring the tensile strength, tensile modulus and percentage of elongation responses by using Tensile Ultimate Machine (UTM) which is compliance to ASTM standard. The speed used to conduct the tensile test is 5 mm/min. The welded sample of aluminium alloy 7075 testing specimen that can be cut by using wire cut machine with the dimension is taken from ASTM E8/E8M-09 standard. The results of ultimate tensile strength, tensile modulus and percentage elongation are calculated and analysed.

In addition, the welding specimens is cut then followed by grind the sample and polished it. Then, the hardness of aluminium alloy can be tested by using Vickers Hardness machine which the testing force is 0.5 kgf and the dwell time is 15 seconds. To observe the microstructure, the sample need to be grind by using grinding machine, then polished it until the mirror surface can be observed. Afterward, the sample is then etched by using Keller's reagent. Microhardness is a dimension of the hardness material when there is huge force applied. The tested been observed and recorded. This research investigates the influence of welding parameters on material characterization of aluminium alloy 7075 and to be optimized by using design of experiment (DOE) through RSM method by single and multi-responses. Besides, the mathematical model will be generated to compare the experimental result and predicted result. The most significant parameter that affected to the responses also will be analysed through ANOVA analysis which the data will be generated using Minitab software.

1.5 Significance/ Important of Study

The rational of research as follows:

(a) From this project, the knowledge about the gas metal arc welding and the important to find the suitable welding parameter can be gained further since there's a lot of articles, journals and reference books that need to be studied and referred in order to complete this research.

(b) Learn about RSM method where the experiment use a sequence of designed experiments to obtain an optimal response.

(c) Scientific learn on how to conduct tensile strength test and hardness test in order to ensure a safe and high quality material.

1.6 Organization of report

(a) Chapter 1 is an introduction part which explains about the background of this project where the objective need to be achieved by following the scope of this project that have been identified.

(b) Chapter 2 is a literature review part explains about all things which interrelated to this project.

(c) Chapter 3 is a methodology part which is an overview of study that explains on how the project been done by following the process and method to be used that have been specified.

(d) Chapter 4 is a result and discussion parts which explains the results that have been collected.

(e) Chapter 5 is a conclusion and recommendation part where it is an overview of the overall project that have been done.

CHAPTER 2

LITERATURE REVIEW

This section is mainly explain the welding process which interrelated towards GMAW process. It describes about the influence of welding parameters in mechanical properties, the hardness at welded area, microstructure at the base metal, HAZ and weldment area, RSM method and other information. The information is collected from reference books, online article, research journal and other foundations as a study perseverance.

2.1 History of Gas Metal Arc Welding (GMAW)

In the year of 1800, Humphry Davy's discovered the electric arc. Initially, carbon electrode were used, nevertheless in the late 1800s, N.G. Slavianoff and C. L. Coffin have been developed the metal electrodes. The philosophies of MIG Welding past started to be established all over the place. In the year of 1920, the automatic welding was presented by P. O. Nobel of General Electric and developed a plain electrode wire worked on through current and arc voltage in place of the origin of amendable the feed rate. The authorised start of GMAW process was effectively industrialised at Battelle Memorial Institute in 1948 underneath the patronage of the Air Reduction Company. This improvement used a gas shielded arc related to the gas tungsten arc but switched the tungsten electrode with a constantly fed electrode wire.

The small-diameter conductor cables and the continuous-voltage power source is the improvement which made the development more functional. The great removal ratio headed handlers to attempt the procedure on steel. The CO2 shielding gas straightaway increased