ENHANCED THE MECHANICAL PROPERTIES OF ALUMINIUM ALLOY 6061 OF WELDING PARTS BY T6 HEAT TREATMENT PROCESS

This report is submitted in accordance with requirement of the University Teknikal Malaysia Melaka (UTeM) for 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 (Engineering Materials) (Hons). The member of the supervisory committee are as follow:

…….....

(Associate Professor Dr. Mohd Amran Bin Md Ali)

ABSTRAK

Objektif utama kajian ini adalah untuk mengkaji kesan parameter rawatan haba T6 pada sifat mekanikal bahagian kimpalan. Proses kimpalan yang digunakan ialah Gas Metal Arc Welding (GMAW). Bahan mentah yang digunakan dalam projek ini ialah Aluminium Alloy 6061 dan dikimpal dengan menggunakan mesin kimpalan robot KUKA. Terdapat empat parameter yang paling penting dalam proses rawatan haba T6 yang telah dikenal pasti, iaitu Suhu SHT, Masa SHT, Suhu Penuaan dan Masa Penuaan. Eksperimen ini direka dengan menggunakan Design of Experiment (DOE) yang merupakan kaedah Taguchi. Kaedah Taguchi dan Analisis Varians (ANOVA) digunakan untuk mengoptimumkan dan mengesahkan parameter rawatan haba. Selepas itu, bahan kerja dipotong menjadi sepuluh sampel dengan dimensi yang diperlukan dalam spesimen bentuk dumbbell dengan menggunakan mesin EDM wayar. Selanjutnya, kesemua sepuluh sampel itu melalui proses rawatan haba T6 iaitu penyelesaian padat, pelindap kejutan dan penuaan buatan berdasarkan parameter yang diperlukan. Kemudian ujian tegangan dijalankan untuk memerhatikan kekuatan tegangan maksimum, modulus tegangan dan pemanjangan peratusan. Nilai kekuatan maksimum untuk sampel asal iaitu tanpa rawatan haba ialah 89.3429MPa, manakala nilai kekuatan sampel maksimum untuk sampel yang menjalani rawatan haba ialah 231.964MPa. Selanjutnya, mikrostruktur sampel yang telah dirawat haba diperhatikan dengan menggunakan mikroskop optik. Ia adalah untuk memerhatikan saiz bijian kawasan kimpal dan logam asas. Akhir sekali, ujian kekerasan Vickers dijalankan untuk memerhatikan nilai kekerasan yang diukur untuk menganjurkan revolusi harta mekanikal kawasan kimpal. Nilai kekerasan untuk sampel asal iaitu tanpa rawatan haba adalah 69.83V, manakala nilai kekerasan untuk sampel yang menjalani rawatan haba adalah 105.17V.

ABSTRACT

The main objective of this study is to investigate the effect of T6 heat treatment parameters on the mechanical properties of welding part. The welding process used is Gas Metal Arc Welding (GMAW). The raw material used in this project is Aluminium Alloy 6061 and welded by using the KUKA robotic welding machine. There are four most important parameters of T6 heat treatment process that have been identified, which are Temperature of SHT, Time of SHT, Temperature of Ageing and Time of Ageing. The experiment is designed by using Design of Experiment (DOE) which is Taguchi method. Taguchi method and Analysis of Variance (ANOVA) are used to optimize and validate the heat treatment parameters. After that, the workpiece is cut into ten samples with required dimensions in a dumbbell shape specimen by using wire EDM machine. Next, all of the ten samples went through T6 heat treatment process which were solid solutioning, quenching and artificial ageing with required parameters. Then the tensile test is conducted to observe the Ultimate Tensile Strength, tensile modulus and also percentage elongation. The value of Ultimate Tensile Strength obtained for original welded sample which is without heat treatment is 89.3429 MPa while the maximum Ultimate Tensile Strength value can be attained for welded sample with heat treatment is 231.964 MPa. Next, the microstructure of the sample that has been heat treated is observed by using an optical microscope. It is to observe the grain size of weldment area and base metal. Lastly, 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 hardness value of original welded sample which is without heat treatment is 69.83 V and the hardness value of welded sample with heat treatment is 105.17 V.

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 all hard working, helpful and supportive

Beloved friends

Syarool Anies Bin Sazali
Nor Azimah Binti Aziz
Fatin Nur Amira Binti Mat Amin
Puteri Nurul Syaza Syahirah Binti Samsudin

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LIST OF ABBREVIATIONS

UTeM	-	Universiti Teknikal Malaysia Melaka
GMAW	-	Gas Metal Arc Welding
SHT	-	Solution Heat Treatment
DOE	-	Design of Experiment
AA6061	-	Aluminium Alloy 6061
UTS	-	Ultimate Tensile Strength
ANOVA	-	Analysis of Variance
UTM	-	Ultimate Tensile Machine
EDM	-	Electro Discharge Machine

LIST OF SYMBOLS

°C	-	Degree Celcius
kgf	-	kilogram-force
%	-	percent
HV	-	Vickers Hardness
R-sq	-	R-square
mm/min	-	milimeter per minute
V	-	Voltage
A	-	Ampere
h	-	Hour
s	-	second
°	-	degree

CHAPTER 1
INTRODUCTION

This section clarifies roughly the background, objective, problem statement, scope of the final year project and followed by the organisation of the final year report. The background discusses about the overview of the process of gas metal arc welding (GMAW) and the process of heat treatment. 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 Research Background

Gas metal arc welding (GMAW) is a welding process where the metal been joined by heating the metals until reach the melting point with an electric arc which 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 by 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 cleaning 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 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.

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. GMAW process is developed to weld aluminium and aluminium alloy by using an inert shielding gas. GMAW are able to weld all metals including nickel, copper and even titanium. Besides, GMAW also capable to weld carbon steel, stainless steel and alloy steel. In order to acquire good 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.

These days, the competition among companies is quite competitive mainly in the manufacturing industries. This is due to endeavour in establishing the new aims to fulfil the customers' demand and satisfaction where they need to identify the best resolution. All the way through the manufacturing revolution era, heat treatment is mostly applied to enhance the mechanical properties of the metals. Heat treatment is able to change the physical properties by monitoring the heating and cooling phases without the shape of the product being interrupted.

In this project, the heat treatment process chosen was T6 heat treatment process. The aims of heat treating is to make the metal stronger, harder and resistance to impact. In general, this heat treatment involves in heating the aluminium alloy at identified temperature and time. Next, is the quenching phase, which is rapid cooling, where the aluminium alloy is quenched in the water at room temperature.

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 heat treatment process. Tensile test is the fundamental mechanical test that can be performed 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 when 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. 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. The solidified grain size and structure are affected by temperature and cooling rate.

Therefore, this project investigates about the influence of heat treatment parameters for instance temperature of Solution Heat Treatment (SHT), time of SHT, temperature of artificial ageing and time of artificial ageing and the output responses which are tensile strength, tensile modulus, percentage elongation, hardness at the welded area and also the microstructure of the base metal and weldment area.

1.2 Problem Statement

The entire research, heat treatment 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. There are a lot of parameters can be used but the most important parameters must be identified to avoid higher material lost due to try and error in order to get the suitable one. This research investigates the influence of heat treatment on mechanical properties for aluminium alloy 6061 and to be optimized by using design of experiment (DOE) through Taguchi method. In the use of DOE such as full factorial, the provision of the sample is too much. Therefore, to overcome this problem, Taguchi method is used to optimize the heat treatment parameters.

1.3 Objectives

The main objective of this project is to investigate to investigate the effect of T6 heat treatment on mechanical properties of welded Aluminium Alloy 6061. To achieve the main objective, the three sub-objectives are outline:

(a) To study the suitable factors of heat treatment such as temperature of solution heat treatment, time of solution heat treatment, temperature of artificial ageing, and time of artificial ageing.

(b) To investigate the responses such as Ultimate Tensile Strength, Tensile Modulus, Percentage Elongation, Hardness of weldment area and the microstructure.

(c) To optimize and validate the heat treatment factors by using Taguchi Method 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. Next, the sample is continued with the heat treatment process using furnace. 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 50mm/min. The welded sample of aluminium alloy 6061 testing specimen that can be cut by using wire cut machine with the dimension is taken from ASTM E8/E8M-09. 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 can be tested by using Vickers Hardness machine which the testing force is 0.025kgf and the dwell time is 15seconds. To observe the microstructure, the sample need to be grind by using grinding machine, then polished it until the mirror surface can be observed. After that, 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. The optimization of heat treatment parameters on mechanical properties for aluminium alloy used Taguchi Method and Analysis of Variance (ANOVA). Data are been analysed using Taguchi Method to define the significant parameter to the output responses.

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 T6 heat treatment process 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 Taguchi method where the experiment does not requires a larger number of experiment to be carried out since it is specially designed to study the entire parameter with lesser number of experiments to be conducted.

(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/Thesis

(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 that related 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 chapter is mainly explain about the welding process that interrelated to GMAW process and T6 heat treatment process. It describe about the influence of heat treatment parameters in mechanical properties, the hardness at welded area, microstructure, Taguchi method and other information. The information is collected from reference books, online article, research journal and other sources as a research purpose.

2.1 Process of Gas Metal Arc Welding (GMAW)

Welding is one of the most applicable joining process in industry. According to (Fang et al., 2014), (Kumar et al., 2013), GMAW which are also known as Metal Inert Gas (MIG) welding and also Metal Active Gas (MAG) welding, produces an electrical arc among the workpiece and a continuously fed electrode that initiating them to soften and join. Besides, the process of shielding gas feeds through the welding gun will protect welding area from pollutants in the air (Ramos-Jaime et al., 2013). Figure 2.1 shows the GMAW process.