MECHANICAL PROPERTIES AND OPTIMIZATION

TIG WELD PARAMETERS

ON ALUMINIUM ALLOY 5052

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering

by

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DECLARATION

I hereby, declared this report entitled Mechanical Properties and Optimization TIG Weld Parameters On Aluminium Alloy 5052 is the result of my own research except as cited in references.

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Date: 26th June 2019

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. The members of the supervisory committee are as follow:

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(PROFESOR MADYA DR. NUR IZAN SYAHRIAH BINTI HUSSEIN)

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(EN. MOHAMAD NIZAM BIN AYOF)

ABSTRAK

Kimpalan Arka Tungsten Gas Lengai (TIG) digunakan untuk mencantum Aluminium Aloi 5052 kerana kosnya yang berpatutan dan dapat menghasilkan kimpalan yang berkualiti berbanding Kimpalan Arka yang lain. Struktur bijian kasar dan pembentukan intermetalik di dalam kawasan kimpalan boleh mengurangkan kekuatan kimpalan ketika proses pengimpalan. Selain daripada itu, masalah lain juga muncul seperti tindakbalas Aluminium Aloi ketika di kimpal dan juga ketidaksempurnaan pada kawasan kimpalan seperti berongga atau retak. Oleh itu, masalah tersebut dapat diselesaikan menggunakan parameter optimum seperti Arus Puncak (A), Arus Rendah (A), dan Kelajuan Kimpalan (cm/min) dari Kimpalan Arka Tungsten Gas Lengai Arus Ulang Alik, Proses kimpalan akan dilakukan menggunakan Robot Kimpalan OTC dengan rod penambah 5356, sambungan temu dengan ketebalan sebanyak 3 mm. Parameter dihasilkan melalui perisian Minitab dan hasil ujian tegangan dijadikan respon dalam hasil kajian ini. Tambahan pula, data akan di analisis menggunakan kaedah Taguchi dan Analisis Varians (ANOVA). Grey Relational Analisis (GRA) adalah kaedah yang efektif untuk proses pengoptimuman dengan jumlah eksperimen yang terhad. Tambahan pula, hubungkait antara parameter mesin dan prestasi mesin dapat diketahui melalui GRA. Oleh itu, parameter terbaik dapat diperoleh dari parameter yang sedia ada menggunakan GRA.

ABSTRACT

Tungsten Inert Gas (TIG) welding is used to join Aluminium Alloy 5052 because of its economic and good quality welds among the arc welding processes. Coarse grain's structure formation and intermetallic formation in the weld zone that can reduce the strength of the weld can occur during the TIG welding process. Other than that, another problem that occurs is the behavior of Aluminium Alloy when being welded and tend to have defect, porosity and solidification cracking. Therefore, these problems can be solved by using the optimized pulsed current parameter such as the Peak Current (A), Base Current (A) Welding Speed (cm/min) of the pulsed current TIG welding. The welding process was performed by using OTC Robot Welding with filler 5356, butt joint with 3 mm thickness of the plate. The design parameter is generated by using Minitab Software and the tensile testing value will be the responses in this research. Moreover, the data will be analyzed by using Taguchi Methodology and Analysis of Variance (ANOVA). Grey Relational Analysis (GRA) is an effective tool for process optimization under limited number experimental runs. In Addition, the relationship between machining parameters and machining performance can be found out by using GRA. Therefore, the best parameter was obtained among the suggested parameter of TIG welding by using GRA.

DEDICATION

I wholeheartedly dedicate this study

to my beloved mother, Mariam Binti Ahmad;

to my father, Muhd Azamuddin Bin Ibrahim;

to my family;

to my helpful classmates and friends;

to my great guider Puan Suraya Binti;

to my honorable and resourceful supervisor, PM Dr. Nur Izan Syahriah Binti Hussein

for assisting me by means of giving me moral supports, knowledge, time, cooperation, encouragement and understandings.

Thank You So Much

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I would like to express my gratitude and deepest thanks to my Final Year Project Supervisor, Profesor Madya Dr Nur Izan Syahriah Binti Hussein for her patience, consistency, guidance and encouragement in helping me with the knowledge of welding professions that she had. Next, I would like to thank to Puan Suraya for her support and guidance on how to write a good report and share helpful knowledge.

Other than that, I had learnt and obtained a good experience based on the journey of completing this project and it is helpful with my study as I get fully understanding about welding process. I am also thankful to other lecturers and staff for their immense in my topic of project, finding the supplier for the material and helping me solve some problems.

In addition, I am grateful to my family, who gave fully support and encouragement whenever I felt discourage and disappointment in completing this project. Last but not least, I would like to thank my friend and colleagues for their support and guide me with the format of the report.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURES

TIG	Tungsten Inert Gas
Al	Aluminium
DOE	Design of Experiment
ANOVA	Analysis of Variance
PCTIG	Pulsed Current Tungsten Inert Gas
FSW	Friction Stir Welding
UW	Ultrasonic Welding
LW	Laser Welding
CMCs	Ceramic Matrix Composites
PMCs	Polymer Matrix Composites
Cu	Copper
Mg	Magnesium
Ni	Nickel
Ti	Titanium
SiC	Silicon Carbide
TiC	Titanium Carbide
GMAW	Gas Metal Arc Welding
SMAW	Shielded Metal Arc Welding
EBW	Electron Beam Welding

LBW	Laser Beam Welding
HAZ	Heat Affected Zone
A	Ampere
Hz	Hertz
MPa	Mega Pascal
DCEN	Direct Current Electrode Negative
DCEP	Direct Current Electrode Positive
Al-Mg	Aluminium Magnesium
Al_2O_3	Aluminium Oxide
cm	Centimetre
min	Minutes
NDT	Non-Destructive Testing
RSW	Resistance Stir Welding
GRA	Grey Relational Analysis
XRD	X-Ray Powder Diffraction
Cr	Chromium
Fe	Iron
Mn	Manganese
YS	Yield Strength
UTS	Ultimate Tensile Strength
BC	Base Current
PC	Peak Current
WS	Welding Speed
OM	Optical Microscope
SEM	Scanning Electron Microscope
S/N	Signal-to-Noise

CHAPTER 1
INTRODUCTION

1.1 Background of Study

Aluminum is a non-magnetic, silvery white ductile and soft metal that is the most abundant metal and the third most abundant element in the earth crust. Pure alloy has low strength compared with the one that has alloying element. According to Singh and Paroothi, (1991), the unique combination of Aluminum-Magnesium (Al-Mg) would enhance the properties of lightweight, moderate high strength, good corrosion resistance, workability and weld ability, and good electrical and thermal conductivity.

One of its applications is in the aerospace industries which are a high-technology industry that produces aircraft, guided missiles, space vehicles, aircraft vehicles, aircraft engines and other parts that related to the work holding fixtures and structural supports. Other than that, aircraft are designed to meet certain standards in terms of flight hours and service life. In order to increase the life-span and service life of many aircraft, welding is used as a cost-effective method and Tungsten Inert Gas (TIG) welding is the most popular metal fabrication joining process in aircraft industry.

Figure 1.1: TIG Welding Assembly Parts (TIG welding, n.d)

Materials that are used in aircraft design are usually ranging from Stainless Steel, Aluminum Alloy, Nickel, Titanium, Cobalt and Niobium. Improvements have been made in terms of advances in aircraft materials and design of airframe structures. Therefore, it is necessary to modify the process parameter based on the type of material being welded.

Table 1.1: Properties of Aluminum Alloy

ALLOY
• A mixture of metals or a mixture of metals with another element.
• The added element (solute) dissolves into the metals that are getting alloyed (solvent) to form a solid solution. It cannot be distinguished.
• Homogenous mixture.
• Do not retain its original properties.
• Have completely different enhanced properties.
• Do not have strict proportions in elemental composition.

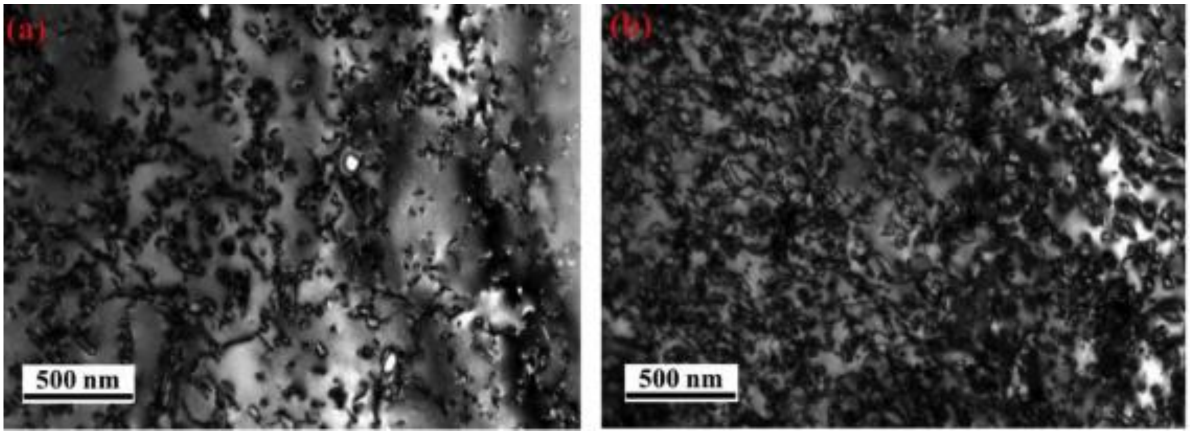

Figure 1.2: Aluminum Alloy (Li et al., 2018)

Although, there are a lot of researches that has been done, the challenges of welding aluminum alloy still occur due to its behavior when welding. Thus, a lot of researches and studies need to be done to improve and enhance the knowledge and understanding of the materials and welding process to get a good quality of weldment by optimizing the parameters. This also can help other researcher or the reader to use this paper as their guideline and do some more improvement to it.

1.2 Problem Statement

In recent years, welding of Aluminum (Al) has been commonly used in automobiles, pressure vessels, components for marine and cryogenic service due to its properties that is lightweight and economical. The usage of Aluminum has been increasing from year to year and Figure 1.1 shows the usage of aluminum in cars since 1975. Aluminum can be classified as one of the materials that is difficult to weld that the steel due to high thermal and electrical conductivity, high thermal expansion coefficient, refractory aluminum oxide (Al_2O_3) formation tendency, and low stiffness. Most fusion and solid-state welding processes can be used to join the aluminum but Tungsten Inert Gas (TIG) Welding is commonly used to weld aluminum.

Nowadays, improvement has been made in terms of the addition of other materials into aluminum to become alloy and it has completely differently enhanced properties which is low density but high strength. According to Wei Zhou (1999), pure aluminum relatively has low strength but with alloy, it becomes stronger than ordinary structural steels which it can be used in armor structures. For example, the Al-Mg alloys of 5XXX series have high strength in the annealed condition and can be strengthened more by cold work. Moreover, steel in various applications in aerospace, marine or automobile industries can be replaced by using Alumnium 5XXX because it has specific strength and good corrosion resistance (Shanavas and Edwin, 2018)

Despite all the advantages, there is a few limitations in Al Alloy that need to be paid attention such as porosity and solidification cracking that can reduce the strength of the weldment and ductility. Chandra and Vivekanand (2013) stated that high porosity and eutectic phases can be found along the inter-dendritic regions. At low melting temperature eutectics, weld cracking occur along the dendritic grains during solidification of the welds. Other than that, it is said that Al Alloy 5052 rod fractured in the weld fusion zone in a brittle sensitivity mode.

There are two types of porosity as shown in Figure 1.3 in aluminum weld joints such as hydrogen induced porosity and inter-dendritic shrinkage porosity that are caused by different factors. Severe porosity need to be taken up seriously due to it can reduce strength, ductility and fatigue resistance of aluminum welds that can cause in reducing in effective load resisting cross-sectional area of the weld joints and increasing the stress concentration at the weld pores, thus reducing the life of aluminum welds.

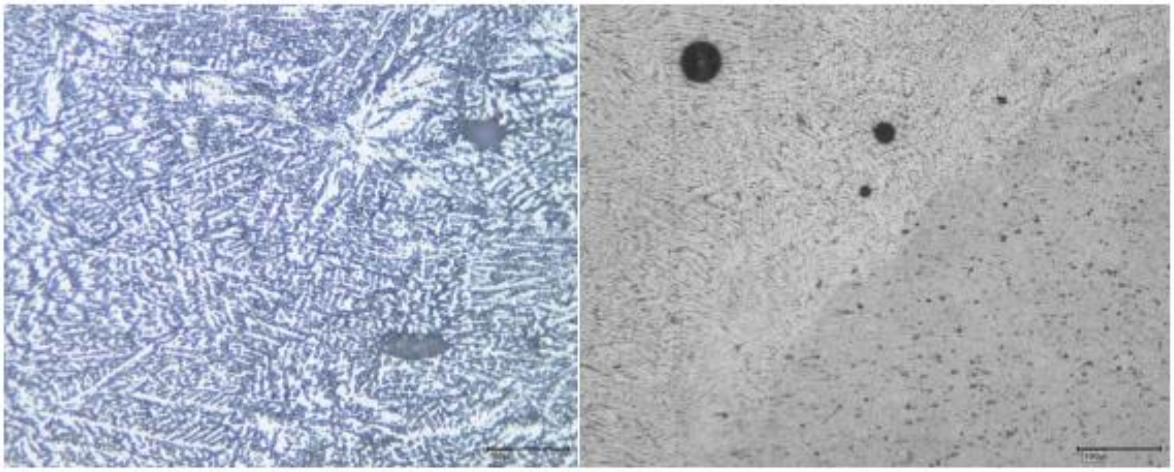

Figure 1.3: Porosity (Chandra and Vivekanand, 2013)

Figure 1.4: Soldification cracking (Chandra and Vivekanand, 2013)

Moreover, other major problems in aluminum welding is solidification cracking as shown in Figure 1.4, that occurred when residual stress developed in the weld. It happens primarily due to two factors such as the development of tensile residual stresses and the presence of low melting point phases in inter-dendritic regions of solidifying weld. According to Emil (2018), it is challenging to weld aluminum due to the high thermal conductivity, melting point of oxides and solubility of hydrogen and in the alloys, hot cracking is commonly occur at the weldment.

Therefore, it is necessary to find an optimal process condition which influences the quality of the weldment. Further research is done to find the optimized parameters such as the Base Current (A), Peak Current (A) and the Welding Speed (cm/min) of the Pulsed Current Tungsten Inert Gas (PCTIG) Welding by using Analysis of Variance (ANOVA).

1.3 Objective

The objectives of this study are:

i. To investigate the effect of TIG weld parameters towards tensile testing on metal alloy, Aluminium Alloy 5052.
ii. To suggest parameter optimization of TIG welding using ANOVA.
iii. To suggest the best parameter among suggested parameter of TIG welding by using GRA analysis.

1.4 Scope of Study

This study focuses on welding using Pulsed Current TIG welding (PCTIG), OTC machine on Aluminium Alloy 5052. The type of joint used on the metal plate was butt joint with a thickness of 3 mm. Parameters such as Base Current (A), Peak Current (A) and Welding Speed (cm/min) were optimized by using Taguchi Method and best parameter among the parameters was suggested by using Grey Relational Analysis (GRA). Design was generated by using Minitab Software. The gas used was pure Argon (99.9%) in this study.

Next, the welding inspection was Non-Destructive Testing (NDT), Optical Microscope and Tensile Testing by using standard ASTM-E8.

1.5 Significance of Study

This study involves the benefit of Aluminium Alloy 5052 in aerospace, automobile and marine industry. Due to the problem and defects such as porosity and solidification cracking occur when welding and, further research needs to be done so that optimized parameters such as Base Current (A), Peak Current (A) and Welding Speed (cm/min) were obtained, thus producing a better strength of weldment and good weld bead geometry and weld quality. Other than that, replacement or maintenance of aircraft parts was expensive, therefore suitable welding and material for the parts can reduced the cost and increased the service life of many aircraft components.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

This chapter reviews on TIG welding's parameters that need to be optimized by using ANOVA on Al Alloy. There is several welding that can be used on Al Alloy such as Friction Stir Welding (FSW), Ultrasonic Welding (UW) and Laser Welding (LW) but TIG Welding will be the main focus in this study. Aluminum Alloy is widely used in aerospace, automobile or marine industries due to its lightweight, high strength and good wear resistances. Therefore, previous researches are included in this chapter to view the problems and detail information for the title given.

2.2 Aluminum Alloy and Its Application

Aluminum is pure metallic element that has silvery white appearance which is mainly found in the earth's crust. Pure aluminum is soft, ductile, corrosion resistance and good electrical conductivity. Moreover, addition of alloy which has a combination of several chemical elements would increase the performance or properties of the pure metal such as aluminum. In conjunction, the alloys can be categorized into non-heat treatable and heat-treatable alloys. Non-heat treatable alloys are mainly found in the 1xxx, 3xxx, and 5xxx series of alloys while the heat-treatable alloys are found in the 2xxx, 6xxx, 7xxx series.

2.3 Welding on Aluminum Alloy

In the automobile industries, minimizing the weight of vehicles is useful and important due to fuel saving, reduction of emission and recyclability. Thus, Aluminum Alloy gives a lot benefits in this industries and others. Moreover, Al has been replacing steel due to its good thermal conductivity which easily dissipates heat. Welding is the permanent joining of two or more pieces of metal to be only single piece by using heat, with or without using pressure. There is various type of welding that can be used to weld Al Alloy. V. Singh and Paroothi, (1991) stated that conventional Metal Inert Gas (MIG) Welding and Tungsten Inert Gas (TIG) Welding processes and innovative Friction Stir Welding (FSW) processes were successfully applied to join 5052-B209 Al Alloy from double sides. Different type of welding has its own advantages and usage. According to Hatem A. Hassan (2018), TIG welding is very versatile, economical and it can be used to weld any metal or alloy over a wide range of thickness. FSW is a modern joining technology process and the common parameter used are the tool rotational speeds and travel speeds. Furthermore, Resistance Spot Welding (RSW) can be used to join the dissimilar alloy 5052 and low carbon steel alloy 1008 and improvement had been made to prevent difficulties in the weldment by drilling process (Zedan and Doos, 2018)). In addition, the derivative of FSW which is Friction Stir Spot Welding has been developed by Mazda Motor Corporation to join the Al panels. It creates spot, lap weld without bulk melting and the tool rotational speed is important to determine the strength of the joint.

Other than that, there are several ways to weld the aerospace materials (Nickel-based alloys) such as TIG, Gas Metal Arc Welding (GMAW), Shielded Metal Arc Welding (SMAW), Electron Beam Welding (EBW), Laser Beam Welding (LBW) and FSW. TIG can be used to weld Ni-based alloys due to it can be weld in any position, clean welding, fully consumption of alloy during welding and require minimal finishing. Next, the benefits of EBM are small area of Heat Affected Zone (HAZ), good depth of penetration, welds width and mechanical properties of weld joint. Other than that, LBW also can be used weld the nickel-based alloys and the output responses such as penetration depth and weld width, mechanical properties like hardness and ultimate tensile load are investigated. Finally, FSW gives better mechanical properties like microhardness and tensile strength from other arc welding process but the process is limited for this material due to the availability of the tool (Choudhury and Chandrasekaran, 2017). According to Tracie Prater (2014), the problem when using FSW is the rapid wear of tool due to dissimilarity of hardness between the material and the reinforcement material. Therefore, certain parameters are being considered and focused to prevent this problem.

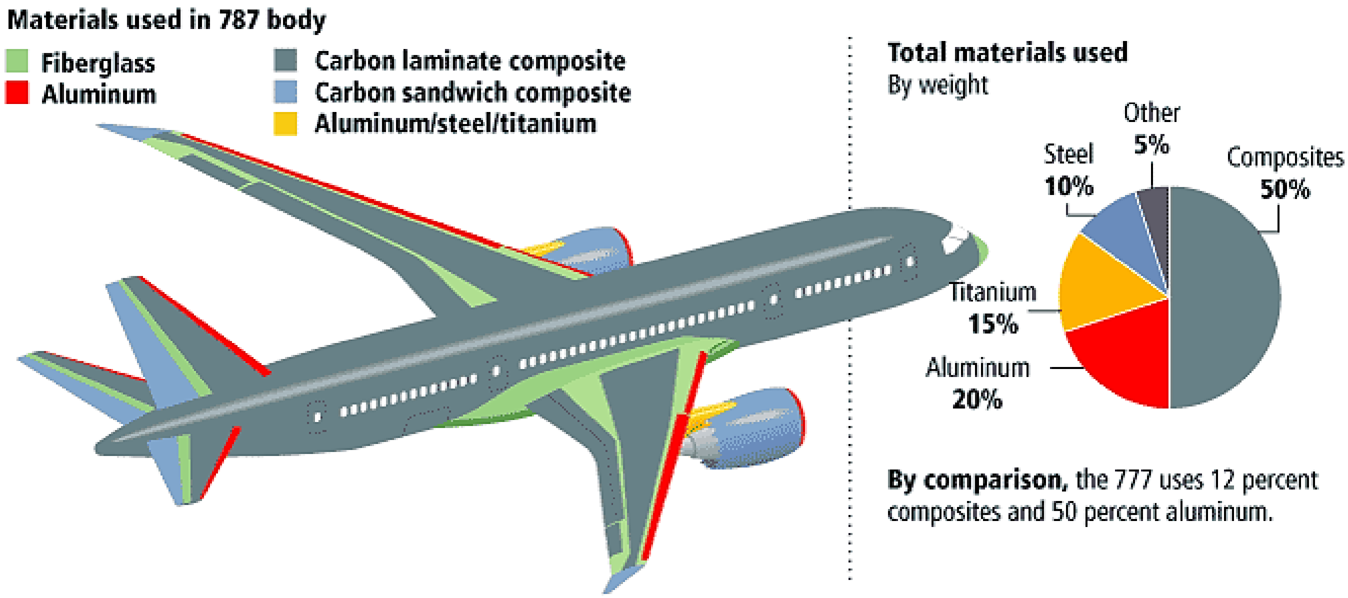

Figure 2.1: Composition of materials for the body of aircraft (Aviation Stackexchange, n.d)

2.4 TIG Welding

TIG is a welding process that uses a non-consumable tungsten electrode to melt the metal and produce arc between the workpiece and electrode with the aid of shielding gas. There are several advantages of TIG welding, and it is commonly applied in shipbuilding, power generation, aerospace, and other industries. (Singh et al.,2017) described that TIG welding produce high quality of welds and very popular in manufacturing industries. Other than that, weld sheet, tube, pipe, plate and castings can be weld using TIG welding. Moreover, Autogenous welding which does not use filler material can be used in TIG welding and it can weld materials up to 3 mm thickness. In paper (A. K. Singh et al., 2017), it uses autogenous welding on dissimilar weld joint of P91 and P22 Steel and the peak hardness and poor impact hardness are observed in the experiment. Moreover, (Choudhury and Chandrasekaran, 2017) stated there are several benefits of TIG welding such as it can be weld in all position, no welding spatter and material loss during welding, and less finishing required. Thus, TIG is one of the suitable welding that can be used on metal matrix composite such as Al Alloy.

Figure 2.2: TIG Welding’s Robot (Cimtec, n.d)