# THE INVESTIGATION OF GMAW PROCESS VARIABLES ON LAP JOINT OF ALUMINIUM ALLOY 5083

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

by

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# DECLARATION

I hereby, declared this report entitled "The Investigation of GMAW Process Variables on Lap Joint of Aluminium Alloy 5083" is the result of my own research except as cited in references.

Signature : ……………………………………
Author's Name : GOGULAN A/L P. MANICKAVELU
Date :

# 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:

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

**(PM.DR. NUR IZAN SYAHRIAH BINTI HUSSEIN)**

# ABSTRAK

Bahan yang digunakan sebagai bahan kerja yang akan disambungkan atau digabungkan dalam kajian ini adalah Aloi Aluminium 5083. Aloi Aluminium 5xxx mengandungi 4.5% - 4.9% magnesium. Kimpalan arka logam gas (GMAW) digunakan untuk menyambungkan aloi aluminium dan komposit aluminium kerana ia merupakan proses kimpalan yang ekonomi dan berkualiti diantara proses kimpalan arka yang lain. Susunan struktur grain dan pembangunan intermetallic di zon kimpalan dapat mengurangkan kualiti kimpalan boleh terjadi semasa kimpalan GMAW. Selain daripada itu, satu lagi isu yang berlaku adalah tingkah laku mekanikal aloi aluminium 5083 semasa dikimpal. Oleh yang demikian, untuk menyelesaikan masalah ini, parameter yang optimum boleh digunakan untuk mesin kimpalan seperti kimpalan voltan, kelajuan perjalanan arka dan kimpalan arus GMAW. Prosedur kimpalan akan dilakukan dengan menggunakan EWM kimpalan robot, kimpalan autogenous, sambungan lap dengan ketebalan plat 3mm. Parameter rekabentuk dicipta dengan menggunakan perisian Minitab dan nilai tegangan dan nila microhardness akan tindak balas dalam kajian ini. Selain itu, kaedah Taguchi dan analisis varians (ANOVA) akan digunakan untuk menganalisis data yang diperolehi daripada experimen ini.

# ABSTRACT

The material used as a workpiece to be joined in this study was Aluminium Alloy 5083. Aluminium alloy 5XXX contains 4.5-4.9% of Magnesium. Gas Metal Arc Welding (GMAW) was used to join aluminium alloys and aluminium composites because of its economic and good quality welds among the arc welding processes. Coarse grain structure arrangement and intermetallic development in the weld zone that can decrease the quality of the weld can happen during the GMAW. Other than that, another issue that happens is the mechanical behaviour of Aluminium alloy 5083 while being welded. Therefore, in order to solve this problem, optimized parameters are used such as welding voltage, arc travel speed and welding current of the GMAW. The welding procedure was performed by utilizing EWM Robot Welding. Autogenous welding, lap joint with 3mm thickness of plate. The design parameter was created by utilizing Minitab Software and the tensile testing value and microhardness value was the reactions in this research. Furthermore, Taguchi Methodology and Analysis of Variance (ANOVA) was used to analysed the data collected from the experiment.

# DEDICATION

**TO MY DEAREST PARENTS,**

Mr P. Manickavelu and Mrs M. Jayanthi

**TO MY BELOVED FRIEND,**

Thanaletchumy a/p Krishna

**TO MY HONOURED SUPERVISOR**

PM.DR. NUR IZAN SYAHRIAH BINTI HUSSEIN

*For her advices, support, motivation and guidance during accomplishment of this project*

**TO ALL STAFF & TECHNICIANS**

*For their direction and advices during completion of this project*

**TO MY SUPPORTIVE FRIENDS**

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I want to say my special thanks to Dr, Zurina binti Shamsudin for her guidance throughout this project, especially in writing report and also for preparing presentation poster according to the required format aspect.

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# TABLE OF CONTENT

# LIST OF TABLES

# LIST OF FIGURES

# LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| GMAW | - | Gas Metal Arc Welding |
| MAG | - | Metal Active Gas |
| MIG | - | Metal Inert Gas |
| AA | - | Aluminium Alloy |
| HAZ | - | Heat Affected Zone |
| DOE | - | Design of Experiment |
| ANOVA | - | Analysis of Variance |
| FSW | - | Friction Stir Welding |
| UW | - | Ultrasonic Welding |
| LW | - | Laser Welding |
| RSW | - | Resistance Spot Welding |
| RSEW | - | Resistance Seam Welding |
| TIG | - | Tungsten Inert Gas |
| LBW | - | Laser Beam Welding |
| FRW | - | Friction Welding |
| PAW | - | Plasma Arc Welding |
| GTAW | - | Gas Tungsten Arc Welding |
| CAR | - | Center of Automotive Research |
| HSLA | - | High Strength Low Alloy |
| HSS | - | High Strength Steel |
| AHSS | - | Advanced High Strength Steel |
| UHSS | - | Ultra-High Strength Steel |
| CFRP | - | Carbon Fiber Reinforced Plastic |
| UV | - | Ultraviolet |
| DCEP | - | Direct Current Electrode Positive |
| DCEN | - | Direct Current Electrode Negative |
| WFS | - | Wire Feed Speed |
| ISO | - | International Organization for Standardization |

# LIST OF SYMBOLS

| | | |
|---|---|---|
| °C | - | Degree Celsius |
| MPa | - | Mega Pascal |
| kWh | - | Kilowatt Hour |
| % | - | Percentage |
| gm/cm3 | - | Gram per Cubic Centimetre |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background of Study

Automotive manufacturing is a high technology industry that produces motor vehicles and components of vehicles. Motor vehicles are designed to meet particular standards in terms of lightweight and service life. In order to increase the life span and service life of automotive components, welding is used as a cost-effective method and Gas Metal Arc Welding (GMAW) is used as joining process in automotive industry. The automotive industry is growing dramatically and it leads to demand for joining process for aluminium alloys.

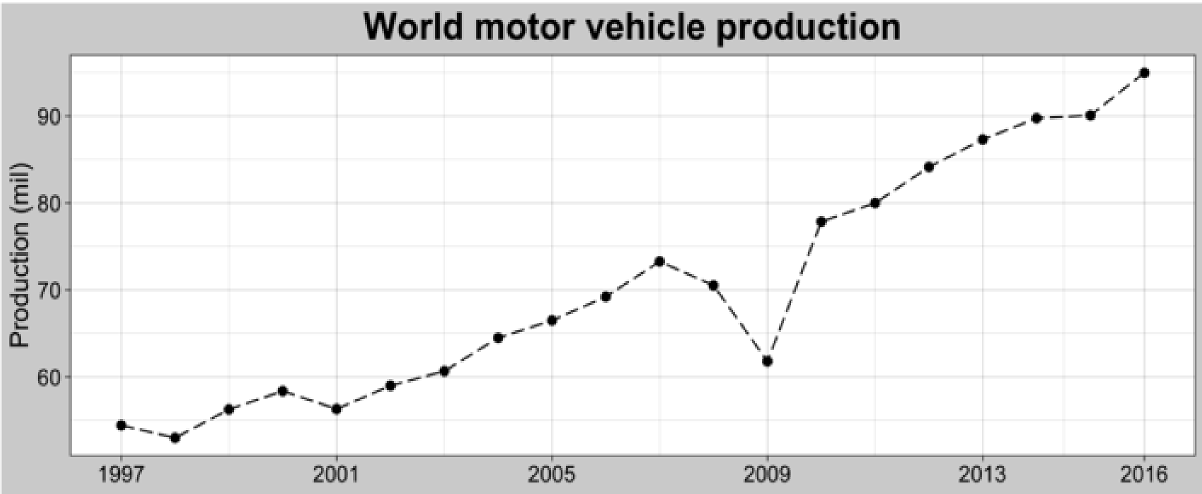


Figure 1.1 World motor vehicle production
(Source: Jakub Krystkiewicz, 2019)

GMAW principles began to be known in the early 19th century. According to Miller, GMAW was invented by P.O. Nobel of general electric in 1920. It is an alternative method of joining technology process. GMAW also usually referred to its subtypes which is metal inert gas (MIG) or metal active welding (MAG). During 1950's and 1960's it become a majorly used process in industrial field after few developments made. The basic necessary equipment of GMAW are welding gun, wire feed unit, welding power supply, an electrode wire and shielding gas supply. Mechanical property of material affected by process variable of welding such as welding current, arc voltage, welding speed, gas flow rate and distance between welding wire and metal.

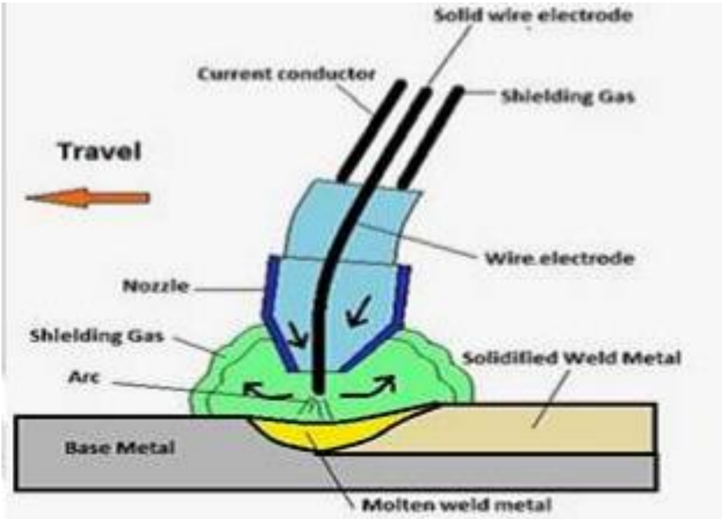


Figure 1.2 Schematic diagram of GMAW (Deshmukh, Lande, Mhaske, & Belkar, 2017)

Material that are used in automotive design are usually ranging from stainless steel, aluminium alloy, nickel and titanium. Improvements has been made in terms of advances in automotive materials and design of structures. Therefore, it is necessary to modify the process based on the type of material being welded. Aluminium alloy is one of the alternative materials to steel which is used in most of constructive due to its unique properties compared to traditional materials. This statement is supported by (Navid Nazemi, 2015) that aluminium alloy enhanced the physical and mechanical properties such as high strength-weight ratio, corrosion resistance, ease of production, high strength, low density, conductivity, heat dissipation and workability.

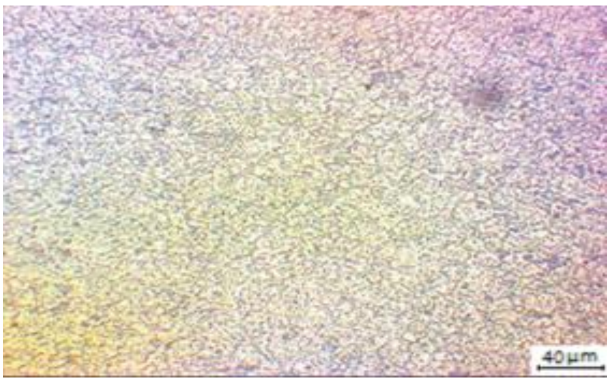


Figure 1.3 Optical microstructure of AA5083 (Subbaiah, 2016)

In this study, 3mm thick 5083 aluminium alloy plates will be welded by GMAW processes in lap joints; the porosity, microstructure, and mechanical properties of the joints will be analyzed.

Thus, this study will investigate the effect of GMAW processes on different welding parameters. The variables parameter in this research are welding current, voltage, and speed.

## 1.2 Problem Statement

In recent years, aluminium alloy usage in automotive has been gradually increasing due to its properties that is lightweight and economical. Aluminium alloy can also classify one of the materials that is difficult to weld because it will not change its colour when it comes nearer to its melting point. Basically, aluminium alloy has few properties which is higher thermal conductivity, thermal expansion and solidification shrinkage rate than steel and tend to oxidize. These are the activities takes place in aluminium alloy during welding process. Welding an aluminium alloy can cause strength weakening, deformation and residual stresses compared to other materials such as steel and etc. According to (Nazemi, 2015), few mechanical changes will occur to the material in the Heat-Affected Zone (HAZ) during welding which will lower the mechanical strength. The final material properties over the weld line is likely to be affected by above phenomenon. Moreover, this can affect the areas that reflected by the temperature absorbed by the metal. Furthermore, the width of Heat-Affected Zone (HAZ) in welded alloys are controlled by the rate of heat input and heat reduction. Concurrently, rate of heat input and heat reduction is depending on few process variables of welding which are arc voltage, travel speed, peak current(A), base current(A), pulse frequency (Hz) and heat transfer. Since, this is new property of material, there are few researches only available using AA5083 along with GMA welding. Therefore, suitable and optimized parameter need to be identified and stated before doing further experiment.

An experiment is desirable to investigate the material properties of the AA5083, besides the effect of GMA welding process variables on the mechanical properties and tensile properties of the material. Therefore, this research is done by using Design of Experiment (DOE) and do the analysis by using Analysis of Variance (ANOVA).

Although there are few studies and researches about the GMAW process variables on lap joints of aluminium alloy 5083, only certain researches that are understand the behaviour of this material which can come out with the best and optimized parameters. However, studies and researches about GMAW process variables on lap joints of AA5083 were still lacking. In this regard, more studies and researches need to be done to improve the quality of the weldment by optimizing the parameters, whereby the findings of this study will be used as reference for further or future research.

## 1.3 Objectives

The objectives of this study are:

i. To design a jig for lap joint of aluminium alloy 5083.
ii. To investigate the effect of GMAW process variables towards the mechanical on aluminium alloy 5083 (AA5083).
iii. To suggest the best set of parameters to weld AA 5083 using ANOVA.

## 1.4 Scope of Study

This study focuses on welding using GMAW, EWM machine on AA5083. The type of joint that will be used is lap joint on the metal plate with a thickness of 3mm. Parameters such as pulse frequency (Hz), peak current (A), base current (A), arc voltage, travel speed and heat transfer will be optimized by using Taguchi method. Design will be generated by using Minitab software. The gas is Argon (99.9%) will be constant parameters in this study. Next the welding inspection are tensile test by using ASTM-E8 standards and Vickers Micro-hardness test by using ASTMC-E92.

At the beginning of the research, the AA5083 need to be cut into a specific dimension (100mm×55mm×3mm) using a shearing machine. The result of the mechanical and tensile properties will be further optimized to find the optimum parameter using the design of experiment (DoE) that has been selected.

## 1.5 Significance of Study

The study involves the benefits of AA 5083 to the automotive industry. Due to different composition and characteristics of this new material further research needs to be done so that optimized parameters such as pulse frequency (Hz), peak current (A), base current (A), arc voltage, travel speed and heat transfer can be obtained, thus producing better strength of weldment and good weld quality. Besides that, replacement or maintenance of automotive parts would be very expensive, therefore suitable welding and material for the parts can reduce the cost and increase the service life of many automotive components. This study also important to identify the successful of GMA welding approach on AA5083. Thus, this study will then be used as a foundation of technology transfer for the industry. In current, there are very limited study in this selected field, this require more knowledge need to be explored.

# CHAPTER 2

## LITERATURE REVIEW

The purpose of this chapter is to present a detailed explanation of the field of study in a sequential order from the previous up to present studies, researches and projects. This chapter introduced the reader a brief and general explanation on types of welding processes and types of joints. It will guide the researchers in developing the project, with familiarizing the concepts, process and any related information which are relevant to the study or project. Furthermore, it will analyse the results and data related to this project to acquire comprehension in composing the methodology. More specifically, this chapter reviews and tracks on GMA welding process variables on lap that need to be optimized by DOE on aluminium ally 5083.

### 2.1 Welding

There are several welding that can be used on aluminium alloy such as Friction Stir Welding (FSW), Ultrasonic Welding (UW) and Laser Welding (LW) but GMA Welding will be the focal point in this study. Aluminium alloys are widely used in aerospace and marine industries due to its lightweight, high strength, and have excellent creep, fatigue and wear resistances. A wide number of automotive body parts are joined together using welding techniques. The improvement of new welding techniques is very significant in automotive industries which will also contribute in new material combinations for auto body parts. In recent days, manufactures prefer welding technique which will contribute lighter yet strong and fuel efficiency. Therefore, previous studies, researches and projects report are included in this chapter to view the problems in detail and relevant information for the title given.

### 2.2 Types of Welding on Automotive Materials

According to Devarasiddappa., (2014) welding is a technique which is used to attach or join two metals permanently through some suitable process variables of welding machine. Welding is essential almost in every automotive industry to repair and fabricate metal products. The most commonly used welding methods for automotive applications are resistance spot welding (RSW), resistance seam welding (RSEW), metal inert gas (MIG), tungsten inert gas (TIG), laser beam welding (LBW), friction welding (FRW) and plasma arc welding (PAW). These methods will explain in detail if following section.

### 2.2.1 Resistance Spot Welding (RSW)

Resistance Spot welding (RSW) is a process of joining overlapping metal sheets (thickness up to 3 mm). The resistance welding is one of the oldest of the electric welding processes in use by industry today. RSW is widely used in automotive, aerospace, rail, metal furniture, electronics and construction. According to (Raut and Achwal, 2014) RSW is crucial in car, bus and railway bodies mainly because of the automatic and fast process. Meanwhile (Ueda et al., 2018) stated that RSW is considered as a major joining method in automotive body manufacturing due to the high productivity and low cost. Advantages of resistance spot welding are low cost method, doesn't need highly skilled worker to handle it, joints made is highly uniform and can be automated or semi-automated operation. However, the equipment cost is high which can influence initial cost, some metals need special surface preparation and thick sheet metals are not easy to weld. The pointed copper electrodes conduct the welding current to the work spot and also serve to apply pressure to form the strong joint as shown in the Fig. 2.1.

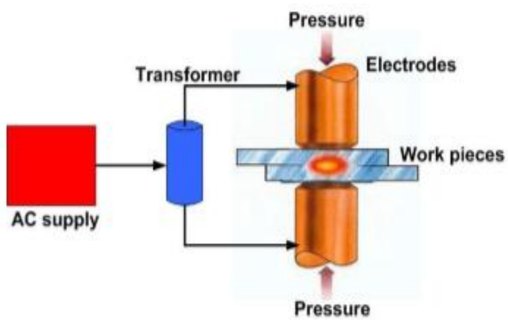


Figure 2.1 Resistance spot welding (Devarasiddappa., 2014)

Figure 2.2 Industrial robots welding car body (Devarasiddappa., 2014)

### 2.2.2 Resistance Seam Welding (RSEW)

The resistance seam welding process is much similar to the resistance spot welding and it involves making a series of overlapping spot welds by means of rotating copper alloy wheel electrodes to form a continuous leak tight joint. The seam welding one of the commonly used process for leak proof and welding joints (Gupta and Moeed, 2015). This process is utilized for making tanks (gasoline), cans, radiators and basin sinks (Gaikwad, Inamdar, and Student, 2007). Resistance seam welding is known for forming the clear weld. Seam welding consist of few advantages such as no gas formation takes place during welding processes, filler material is not required during this method, seam welding also can be automated and can form the gas-tight as well as liquid tight joints with the help of continuous spot welding. At the same time, highly-skilled labour is needed to handle the speed of the roller as per the situations and the machinery used in seam welding has a very high price. Moreover, seam welding is very difficult to weld sheet metals which have a thickness larger than 3mm.

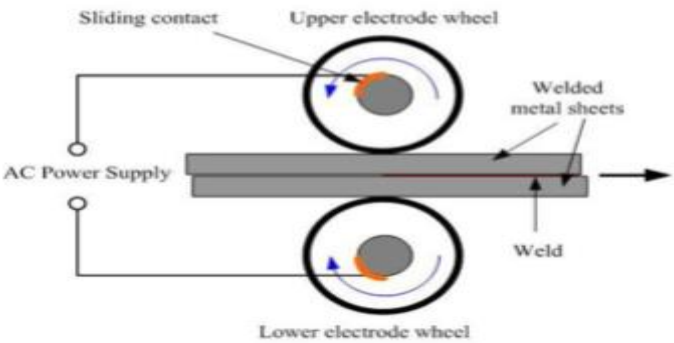


Figure 2.3 Principle of resistance seam welding (Devarasiddappa., 2014)

Figure 2.4 RSEW producing continuous joint (Devarasiddappa., 2014)

### 2.2.3 Plasma Arc Welding (PAW)

Plasma is the condition of the issue when some portion of the gas is ionized making it a channel of electric flow. According to (Wu, Wang, Ren, and Zhang, 2014) plasma arc welding is an arc welding process where metals are melted and joint by heating them with a constricted plasma arc occurs in the middle of tungsten electrode and metals. Plasma welding is very similar to TIG as the arc is formed between a pointed tungsten electrode and the workpiece. However, by positioning the electrode within the body of the torch, the plasma arc can be separated from the shielding gas envelope. Plasma is then forced through a fine-bore copper nozzle which constricts the arc. The arc utilized in PAW is contracted by a little nozzle and has a lot higher velocity (300–2000 m/s) and heat input intensity (109–1010 W/m2) than that in conventional gas tungsten arc welding (GTAW). As a result, PAW has numerous favourable circumstances over GTAW, in terms of penetration depth, joint preparation and thermal distortion etc. Following are the favourable circumstances of plasma arc welding such as higher heat concentration and plasma jet allows faster travel speed, heat affected zone is smaller compared to GTAW, provides more freedom to observe and control the weld and torch design allows better control of arc. While the disadvantages are plasma welding equipment are very costly, requires training and specialization to perform plasma welding and it produces ultraviolet and infrared radiation.