UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DOE Approach in Determination of the Optimum Welding Parameters for Three Layer Spot Weld

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Mechanical Engineering Technology (Maintenance Technology) with Honours.

by

MUHAMMAD SYAHRUL NEZAR BIN MOHD AMER

B071410029

910608-02-5963

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering Technology (Maintenance Technology) with Honours. The member of the supervisory is as follow:

………………………………
(Project Supervisor)

ABSTRAK

Kimpalan rintangan bintik biasanya digunakan dalam industri pembuatan dan automotif; kerana kelebihan kimpalan ini seperti kelajuan yang tinggi dan hasil pengeluaran yang tinggi, kesesuaian untuk automasi, mudah diproses dan berkos rendah. Secara amnya, percubaan dan kaedah kesilapan pengetahuan dan pengalaman pengimpal telah digunakan secara meluas oleh industri untuk pemilihan parameter kawalan kimpilan optimum untuk mencapai kimpalan yang berkualiti. Projek ini berkait dengan pengkajian tentang mikrostruktur dan ciri-ciri mekanikal logam kimpalan yang menggabungkan keluli AHSS dan SPCC. Objektif utama projek ini untuk mencari parameter yang optimum terhadap kimpalan rintangan bintik untuk tiga lapisan. Untuk reka bentuk eksperimen, Design Faktor telah dipilih dengan menggunakan perisian Design Expert, dan jumlah lapan set percubaan dengan tiga jenis faktor seperti masa kimpalan, kimpalan elektrik, dan daya elektrod telah dijalankan. Kajian sifat-sifat mekanik adalah terdiri dengan menggunakan dua ujian; ujian tegangan, dan mikrostruktur dan menganalisis sifat-sifat mekanikal dan kualiti rintangan tempat kimpalan selama tiga lapisan. Analisis varian teknik (ANOVA) telah digunakan untuk menyemak kecukupan model maju dan F-ujian telah digunakan untuk menentukan parameter yang paling penting serta mempengaruhi parameter kimpalan bintik. Hasil kajian menunjukkan semasa kimpalan memainkan peranan penting dalam menentukan kekuatan tegangan maksimum.

ABSTRACT

Resistance spot welding (RSW) is commonly used in manufacturing and automotive industry; because of their advantages such as high speed and high production, suitability for automation, easy to process and low cost. Generally, the "trial and error" method based on the knowledge and experience of the welder has been widely adopted by the industry for the selection the optimum parameters in order to achieve a good quality of welds. This project deals with the investigation of microstructure and mechanical properties of weld joint of AHSS and SPCC. The main objectives of this project to find the optimum parameters of resistance spot welding process for three layers. For the design of the experiment, the Full Factorial Design was employed by using Design-Expert software, and total eight runs of experiment selected three factors such as weld time, weld current, and electrode force was conducted. The studies of mechanical properties are consisting by using two tests; tensile test, and microstructure and also analyze mechanical properties and quality of resistance spot weld for three layers. Analysis of Variance (ANOVA) technique was used to check the adequacy of the model developed and F-test has been used for determining the most significant parameters affecting the output response. As a conclusion, the result shows that the weld current plays an important role in determining the maximum tensile strength and nugget size.

DEDICATION

To my beloved mother Mrs. Asmanaini Binti Salleh and my beloved father Mr. Mohd Amer Bin Salleh

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I would like to express my deepest appreciation to the people who support me to finish this report. Firstly, special thanks to my final year project supervisor, Mr. Mohd Harris Fadhilah Bin Zainudin, because has given guidance and advice to finish my report and not forget to my co-supervisor Mrs. Rahaini Binti Mohd Said because provide additional information that related with my research. Special appreciate also to the other lecturer that given extra knowledge and idea to improve my writing and also to the panels that help me to improve my presentation and my report. Lastly, special thanks to my parents that give me encouragement while finishing this report.

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LIST OF ABBREVIATIONS, SYMBOLS, AND NOMENCLATURE

RSW	-	Resistance Spot Welding
AHSS	-	Advanced High Strength Steels
DOE	-	Designs of Experiment
ISO	-	International Standard Organization
UTM	-	Universal Testing Machine
SPCC	-	Cold Rolled Commercial Grade
AC	-	Alternating Current
SEM	-	Scanning Electron Microscope
l	-	Length
mm	-	Millimeter
RSM	-	Response Surface Method
TRIP	-	Transformation Induced Plasticity
UTS	-	Ultimate Tensile Strength
MART	-	Martensitic Steel
MPa	-	Megapascal
HAZ	-	Heat Affected Zone
FZ	-	Fusion Zone
BM	-	Base Metal
ANOVA	-	Analysis of Variance

CHAPTER 1

INTRODUCTION

Background of the Experiment

Resistance spot welding (RSW) is one of the main techniques metal joining for high volume production in the car manufacturing industry (Singh et al 2013). In addition, a good design and combinations of material reducing vehicle mass, low fuel consumption and more importantly is the integrity of structure which increases the crashworthiness of vehicle. RSW is one of the cleanest and efficient processes for fabrication metal sheet.

Production of car assembly typically consist about 2000-5000 of spot welds and to ensure the production optimization, resistance spot welding plays an important role used for bonding during automotive assembly (Pouranvani et al 2013). There are many advantages of this process such as fast, inexpensive cost and automation feasibility. Furthermore, resistance spot welding also does not change much of the weight of a material compared to other welding technique such as arc welding (Aravinthan et al, 2011).

Spot welding in the automotive industry is for joining two or more metal plates in producing make the complete units of cars. The process is involved two or more overlapped components and then the current is flowing through the electrodes. Heat is generated due to the resistance of the parts being welded (Majid 2016). This machine normally operates manually or automatically depends on usage and situation.

In resistance spot welding, there are several welding parameters involved in the process such as welding current, welding time and electrode force applied. Achieving good weld quality starts with a good process design that controls the parameters during the welding process. Generally, optimization is the process of estimating the potential minimum value of machining performance at the optimal point of process parameters involved (Muhammad & Manurung 2012).

Problem Statement

The biggest challenge in the automotive industry today is the durability, reliability, and sustainability. The new technologies have come out and developed in the field of resistance welding which it plays an important role in assembly car components. Therefore, the ways to weld sheets metal for the automotive industry sector generally use resistance spot welding technique due to its high ability for automation, low cost and complexity (Andersson et al. 2016).

Resistance spot welding has some advantages which include less deformation of the weld, not used of filler and also a cost-effective process. In addition, it is cheap for the process, provide dimensional accuracy and faster of the process where the case of operation and its adaptability for automation in the production of sheet metal assemblies are major advantages (Shahid 2015).

Material selection is an important stage to design the vehicle for reduction of vehicle mass but at the same time have high mechanical strength. It has been observed as a result of increasing requirements for passenger safety, vehicle performance, and fuel economy. The response of steel industry to the new challenges is a rapid development of higher strength steels, named Advanced High Strength Steels (AHSS) (Kuziak et al. 2008).

An increased awareness of the energy saving and environmental make an effect in demand for lightweight vehicles. Industry automotive has considered being used advanced high strength steel sheet into an automotive part in order to reduce the weight and crashworthiness enhancement (Liu et al. 2014). Due to lightweight itself, the consumption of fuel is automatically reduced. AHSS have better performance in a crash compared to classical high strength steel with higher work hardening rate and high flow stress (Kuziak et al. 2008).

Spot welds play an important role for automotive structural assemblies to transfer load through the structure during the crash. Additionally, spot weld can also act as to manage impact energy. Resistance spot weld joint failure has been identified as one types of a problem when a vehicle crash occurs. Therefore, stiffness, strength, and integrity of car body structure or any structure composed of sheet metals highly depend on the good quality of weld which controlled the parameters properly (Pouranvari & Marashi 2011).

Commonly problem occurs in resistance spot welding is the setting for appropriate parameter to obtain an optimum value which affects a high- quality spot weld joints (Rawal et al. 2016). This happens because of different ways in which metals respond to heat. The optimum parameters are important to estimate the maximum strength of mechanical properties. Previously the method to determine optimum parameter usually depends on trial and error (Saleem et al. 2013). However, these methods are expensive and time-consuming. In order to overcome this problem, Designs of Experiment (DOE) method have been used to determine desirable welding parameter in spot welding.

Objective

Based on the background and problem statement that has been stated, the objectives of this experiment are:

1. To find the optimum parameters of resistance spot welding process for three layer spot weld.
2. To test and analyze mechanical properties and quality of resistance spot weld for three layers.

Scopes

In order to achieve the objective, several scopes have been determined.

1. Optimization the parameters of resistance spot welding process such as weld time, weld current, and electrode force by using the full factorial Design of Experiment (DOE).
2. Testing the specimen by using Universal Testing Machine tensile shear test according to ISO 7500-1 to find a stress-strain curve and Scanning Electron Microscopy to observe microstructure of weld nugget.
3. Analyzing the highest stress-strain curves from varying the parameters of resistance spot welding.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

This literature review was performed to study and analyze the resistance spot welding, welding parameters, the principle of resistance welding, and the design of experiment method (DOE). Besides that, this chapter includes the overview of material SPCC and AHSS which will be used in the three layers spot weld process.

2.2 Types of Resistance Welding

Resistance welding is a welding technology which grows fast and widely used in manufacturing industry especially in automobile and aircraft industries for joining metal sheets and components (Nasir 2016). The welding process is done by applying a strong current through the metal combination which heat is produced and finally melt the metals at the localized point (Pouranvari & Marashi 2013). The process is predetermined by the design of the electrodes and the workpieces to be welded.

Welding parameter such as a force is applied before, during and after the application of current to joint the contact area at the weld interfaces. Resistance welding can be classified into several types according to its shape of workpieces and form of electrodes. Those are resistance spot welding, resistance projection welding, resistance seam welding, and resistance flash welding.

Resistance Projection Welding

Projection welding is a type of resistance welding process using projections, embossments, or intersection where heat and pressure are applied during the welding process. This welding process typically has three types projection welds design such as embossed, stud-to-plate and annular. Figure 2.1 shows to make a joint; welding heat is localized by making projection or embossments on one or both of the workpieces using specially design electrode. Commonly the electrodes are designed flat and big and its material made from copper based alloys. The projection welding is suitable for materials that contain low carbon steel, coopers' alloys, coated and plated steels and the others.

This type of welding requires less welding current, pressure, and suitable to be automated. However, it has a limitation which is weldability of thin workpiece and requirement to add the step of operation after welding process is over. Projection welding is widely used in assembling automobile components such as nuts and stud attached to seats, produce shock absorbers, and for hollow metal doors frames.

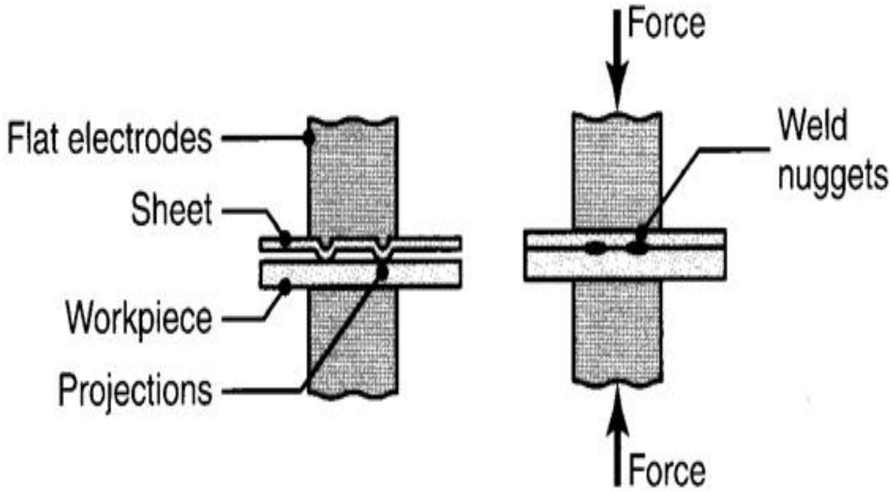

Figure 2.1: Schematic Diagram of Projection Welding

Source: (http://www.mechscience.com/)

Resistance Spot Welding

Resistance spot welding is one of the oldest of the electric welding process. It is also one of the popular types of welding used in joining metals sheet (Nasir 2016). It is widely used in automotive industry to assemble the body in white of vehicles. It uses two copper electrodes tips and then presses the worksheets together to form a weld. Resistance spot welding is a process of joining metal components by the fusion at discrete spots at the interface of the workpieces (Goodarzi et al. 2009). A weld nugget is formed which melted the metal in the joint at the interface due to the resistance of the base metal to electrical current flow. The combination of variable parameters affects the strength of welded. The strength can be determined based on formation nugget size and conducted a mechanical test for pull-out and interfacial failure (a. Aravinthan and C. Nachimani 2011). Other than that, material thickness and type play an important role to determine the amount of current time flow in the joint. Figure 2.2 below shows the schematic drawing on how spot welding works.

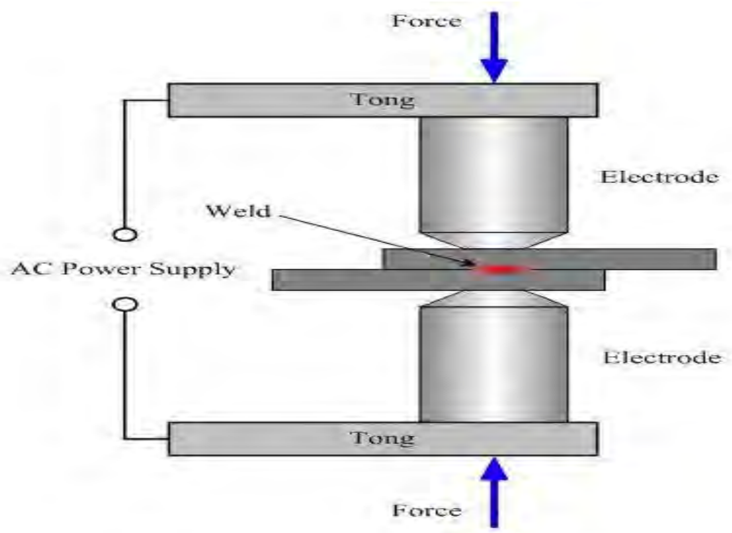

Figure 2.2: Schematic Diagram of Resistance Spot Welding
(Sahota et al. 2013)

Resistance Seam Welding

Resistance seam welding is quite similar to spot welding but roller electrodes are used for this process. Figure 2.3 shows the operation of seam welding which copper roller electrodes are used to provide a continuous run of overlapping welding process where electric current is supplied. The amount of heat is produced which it melts the sheet and together formed between surfaces molten. The joints are then made stronger by the pressing force applied. Important factors for maintaining consistency and producing a good seam weld nugget are the welding force, welding current magnitude, welding speed, electrode shape and the mode of current being supplied.

The common applications of resistance seam welding in industries are used to make fuel tanks for motor vehicles. Besides, it is also used to fabricate steel drums, tin cans, and domestic radiators. However, some of the disadvantages of resistance seam welding are a high cost to set-up the equipment and difficult to weld metal that having a thickness greater than 3 millimeters.

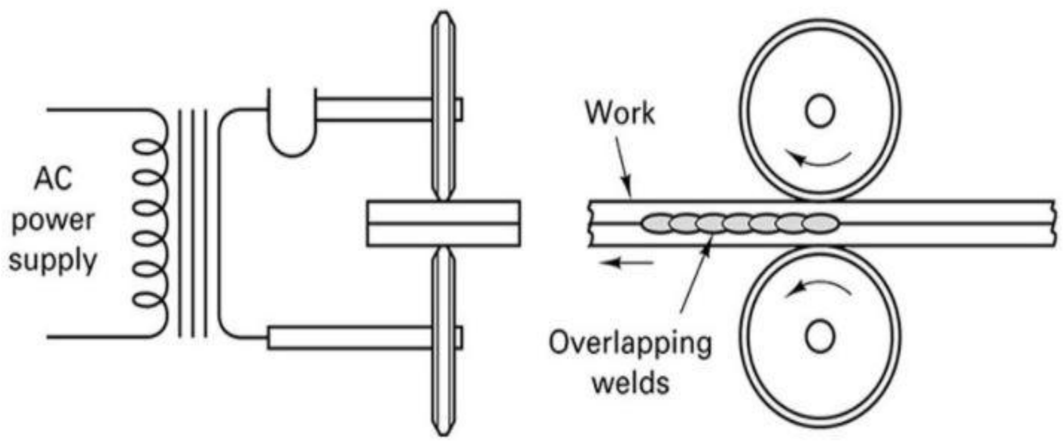

Figure 2.3: Schematic Diagram of Seam Welding
(Saleem et al. 2013)

Resistance Flash welding

Resistance flash welding is a welding process that joining thick metal plates or bars (Moarrefzadeh 2012). The workpiece to be joined does not move and clamped rigidly. The movable clamping mechanisms that clamp the other workpiece move until contact each other. Pressure is applied and heated by an electric current passing through the contact area and producing a weld. The arms are connected to the transformer power supply sources unit. After the process is completed, the clamp releases the workpiece. Figure 2.4 shows the movable part is conveyed nearer to the altered workpiece and as these workpieces come nearer to each other. Furthermore, a short circuit takes place which leads to arcing or flashing. At the interfaces, these flashings produce heat and bring to the forming temperature. At this part, the workpieces are forged along to form a welding joint.

The application of resistance flash welding is normally applied for producing joints in long tubes and also for pipes. It is widely used in the automotive industry to make wheels rim, wire pipes and also be applied to railway track joint.

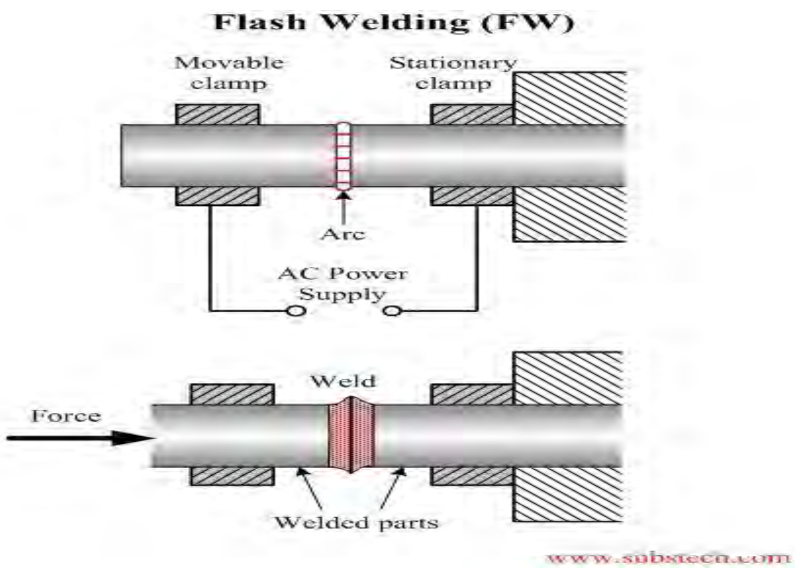

Figure 2.4: Schematic Diagram of Flash Welding

Source: (http://www.substech.com/)