UNIVERSITI TEKNIKAL MALAYSIA MELAKA

# Investigating the Welding Parameters Performance of Spot Welding Process

Thesis submitted in accordance with the requirements of the Universiti Teknikal Malaysia Melaka for the Degree of Bachelor of Engineering (Honors) Manufacturing (Process)

By

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# APPROVAL

This PSM submitted to the senate of UTeM and has been as partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Manufacturing Process). The members of the supervisory committee are as follow:

………………………………

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# ABSTRACT

This project is to expose a research about parameter that influences a particular process in the application of spot welding machine. The objective of this experiment is to investigate the welding parameters performance in welding zone and its mechanical properties and then the “Dog Bone” specimen is used in the tensile test and microstructure. The material used is Galvanized Iron (GI). The experiment will be held in the Welding Lab and Material Lab, Universiti Teknikal Malaysia Melaka. The type of machine used in this research is Spot Welding Machine of Miller USA. There are various types of parameter that influence the mechanical properties of welding zone and microstructure welding zone on the spot welding machine where in this experiment the parameter that will be investigate are “Weld time”, “Squeeze time” and “Weld current”. To measure and examine the mechanical properties and microstructure of the dog bone product, Universal Testing Machine (UTM) and Optical Microscope will be used to test the strength and examine microstructure on the product. From the data achieve, the appropriate parameter for the joining will be found based on the testing process. Parameter such as weld time, weld current and squeeze time will be considered to get the strong and sturdy of the joining. By controlling those parameters, the quality of spot welding joining can be enhanced.

# ABSTRAK

Projek ini adalah kajian bekenaan parameter yang mempengaruhi sesuatu proses didalam aplikasi kimpalan bintik. Objektif eksperimen ini dijalankan adalah untuk menyiasat parameter-parameter dalam kimpalan pada zon kimpalan dan ciri-ciri mekanikal zon kimpalan pada permukaan “Dog Bone” iaitu sejenis spesimen yang digunakan dalam ujian tegangan dan mikrostruktur. Bahan yang digunakan untuk menghasilkan produk ini ialah dari jenis Galvinized Iron (GI). Eksperimen ini dijalankan di Makmal Kimpalan dan Makmal Bahan, Universiti Teknikal Malaysia Melaka dan mesin yang digunakan untuk menghasilkan produk ini adalah mesin kimpalan bintik jenis Miller USA. Terdapat pelbagai parameter yang mempengaruhi ciri-ciri mekanikal zon kimpalan dan mikrostruktur zon kimpalan pada sesebuah mesin kimpalan bintik dan parameter yang dikaji dalam eksperimen ini ialah “Masa kimpalan”, “Masa himpitan”, dan “Arus kimpalan”.Bagi mengukur dan memeriksa cirri-ciri mekanikal dan mikrostruktur tahap kelenkungan permukaan dan keadaan permukaan produk, Mesin Ujian Universal dan Mikroskop Optik akan digunakan untuk menguji kekuatan dan memeriksa mikrostruktur pada produk. Daripada ujian yang dilakukan, parameter yang sesuai untuk kimpalan akan dapat dijumpai. Parameter seperti “Masa kimpalan”, “Masa himpitan”, dan “Arus kimpalan” dipertimbangkan bagi mendapatkan sambungan yang kuat dan kukuh. Dengan mengawal parameter-parameter ini, kualiti sambungan menggunakan kimpalan bintik dapat dipertingkatkan.

# DEDICATION

For my beloved parent, my family and to those who's with me all this time.

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# NOMENCLATURE

| | | |
|---|---|---|
| Bar | - | Unit for Pressure |
| C | - | Celsius |
| cm | - | Centimeter |
| DOE | - | Design of Experiment |
| Eq | - | Equation |
| F | - | Fahrenheit |
| FEM | - | Finite Element Method |
| GI | - | Galvanized Iron |
| Gpa | - | Giga Pascal |
| HAZ | - | Heat-affected Zone |
| I | - | Current |
| K | - | Kelvin |
| kA | - | Kilo Ampere |
| kN | - | Kilo Newton |
| Kpa | - | Kilo Pascal |
| kVA | - | Kilo Volt Ampere |
| MIG | - | Metal Innert Gas |
| mm | - | milimeter |
| Mpa | - | Mega Pascal |
| R | - | Resistance |
| RSW | - | Resistant Spot Welding |
| SAW | - | Submerge Arc Welding |
| SMAW | - | Shield Metal Arc Welding |
| s | - | Second |
| t | - | Time |
| TIG | - | Tungsten Innert Gas |
| UTM | - | Universal Testing Machine |
| UTeM | - | Universiti Teknikal Malaysia, Melaka |
| V | - | Volt |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background

Microstructure of the material is an important element and the investigation of its characteristic including the material types and mechanical properties of the material are necessary. Every material has their microstructure that differentiates than other material. Microstructure is the structure that is observed when a polished and etched specimen of metal which can be viewed under an optical microscope at magnifications in range of approximately 25x to 1500x. Material that used at any industries has a different characteristic especially in their mechanical properties such as tensile strength, density, heat capacity, melting point and others. For example, in the spot welding process, we need the suitable size and metal to perform by the spot welding process such as thickness of the specimen, types of the specimen in order to get a good quality welding joining. Each metal that have underwent the spot welding process had the different microstructure on the welding zone because each material do not have the same characteristic. So, the different result can be produced for each process that involving the different material.

The purpose of this project is to study the microstructure in welding zone of spot welding process. It investigates the mechanical properties and microstructure of the weld zone of Galvanize Iron (GI). The material of GI was chosen because this material application is mostly popular in manufacturing industries such as automotive industries especially in body car manufacturing. This is because GI is so strong and sturdy in light weight.  As the result, GI is the good material to use in this investigation.

At the end of this study, the selection of optimum parameters that suitable with the material has been determined and those are weld time, weld current and squeeze time. Then, the strength of welded material will be tested with the Universal Testing Machine (UTM) and Optical Microscope is used to identify the structure of the GI’s microstructure.

## 1.2 Problem Statements

In spot welding process, many defect and problem occurred on the specimen, especially on the joining part which affected the microstructure of welding zone. The defects are:

1) Crack and fracture due to the lower current and short welding time.
2) Brittle fracture affected by the lower current support during performing the welding process.

## 1.3 Aims and Objectives

Aims of this study is to investigate the microstructure of welding zone by using spot welding process. The main objectives that involved of this study have been listed down.There are:

1) To investigate the parameter influences that affected the performance of the joining.
2) To examine the microstructure and mechanical properties of welding zone by using the spot welding.
3) To study the relationship of parameters with the mechanical properties of the weld joining.
4) To determine the appropriate parameters for better performance of the joining.

## 1.4 Scope of Study

In order to achieve the above aim and objectives the following tasks are required to be performed:

1. Literature review

Reviewing the relevant theories and other researchers' findings in order to:

- Understands to concepts of spot welding.
- Identify parameters that influence the performance of spot welding process.
- Understands the microstructure of the weld zone.
- Show types of microstructure of welding zone.
- Understands the mechanical properties of weld joining.

2. Process study of spot welding
    - Familiarization of spot welding process.
    - Identify the parameters that chose for the process.
    - Examine the microstructure of weld zone of spot welding process.
    - Analyze the mechanical properties of the weld joining.

3. Determine and established the appropriate method to analyze and examine the microstructure of the weld zone
    - Understand the optical microscope and universal testing machine including the procedure both of them in engineering problems.
    - Develop the methodology to apply universal testing machine and optical microscope to investigate the strength of the joining and examine the microstructure.

4. Analyze data and examine the microstructure of weld zone
    - Find out the tensile strength of the welding joining
    - Find out the structure of microstructure of the weld zone.

5. Implementation into experiment
    - Determine the parameters for the experiment.
    - Prepare the machine and perform the experiment.
    - Determine the structure of the microstructure and welding joining strength.
    - Analyze and compare experimental results.

From the above scope of study, the study of microstructure in weld zone by using spot welding process will be performed according to the methodology. The next section generally describes the structure of this study.

# CHAPTER 2

## LITERATURE REVIEW

### 2.1 Introduction

Lin et al. (2007) found that in the spot friction welding process, the important processing variables are tool geometry, tool rotational speed, tool holding time and tool downward force. Optical and scanning electron micrographs of the welds before and after failure under quasi-static and cyclic loading conditions are examined. Beside that, under high-cycle loading conditions, the experimental observations suggest that one fatigue crack appears to emanate from the original crack tip and another fatigue crack appears to emanate from the bend surface. It should be emphasized that the kinked fatigue crack model presented earlier is approximate in nature by considering that the weld geometry of the spot friction welds is different from that of the resistance spot welds.

Hinrichs et al. (2004) several methods had been used to identify the most optimum processing parameters for the failure strengths of spot friction welds in lap shear and cross-tension specimens of aluminum 5754-O sheets with considerations of different tools.

Lin et al. (2004) studied the microstructures and failure modes of spot friction welds in lap-shear specimens of aluminum 6111-T4 sheets using optical micrographs.

Marya et al. (2005) found that the effects of several process parameters (including weld current, weld time, and weld force) on zinc expulsion, mechanical properties, defects, and microstructures of resistance spot welds were all studied in relation with the two major types of weld fracture. Beside that, in contrast, the difference of 10% for their sheet thickness was responsible for smaller weld diameters; lower weld tensile-shear forces, larger shrinkage voids, and more frequent interfacial fractures in welds from the thicker DP600 steel. For the two steels, occurrence of weld interfacial fracture was eliminated using long weld times (>20 cycles), low currents (<9 kA), and high forces (>900 lb, or 4.0 kN); i.e., process parameters that increased weld diameters while preventing zinc ingestion into the fusion zone. Weld current and weld time were varied between 7 and 40 kA and between 2 and 40 cycles, respectively. Many welds, fabricated with identical parameters, were tensile sheared to quantify their load-carrying capabilities, and, despite loading conditions different than in the chisel test, determine if one steel was also more prone to spot weld interfacial fracture than the other. Low currents (<10 kA), extended weld times (>25 cycles), and high weld forces (>900 lb, or 4.0 kN) promoted weld button formation by producing large fusion zones and occasionally deep (but acceptable) electrode indentations. Galvanized coatings generally have insignificant effects on weld fracture. However, decreasing weld time and increasing weld current (not typical in production) resulted in zinc ingestion into the fusion zone, which caused solidification cracks. In this investigation, ingestion of zinc was observed at the same time type of fracture changed from one type to the other.

Ichiyama et al (1996) stated that, since weld diameter is well known to be a key player in weld fracture, weld diameters were measured and correlated to the process parameters, as were the weld microstructures.

Park (1993) found that due to the rapid heating and subsequent cooling; weld microstructures are considerably different from pre-existing microstructures.

Hou et al. (2007) who conducted finite element analysis for the mechanical features of resistance spot welding process in their paper, a 2D axisymmetric model of thermo-elastic–plastic finite element method (FEM) is developed to analyze the mechanical behavior of resistance spot welding (RSW) process using commercial software ANSYS.

H. TANG et al (2003) who investigated about mechanical characteristics of resistance spot welding machines, such as stiffness, friction and moving mass, have complex influences on the resistance welding process and weld quality. The mechanisms of the influences are explored by analyzing process signatures, such as welding force and electrode displacement, and other process characteristics, such as electrode alignment. Machine stiffness and friction affect welding processes and weld quality.

R. Kacar et al. (2006) have been studied about the resistance spot weldability and found that the influence of the primary welding parameters affecting the heat input such as; peak current on the morphology, microhardness, and tensile shear load bearing capacity of dissimilar welds between AISI 316L austenitic stainless steel and DIN EN 10130-99 (7114 grade). Beside that, the optimum welding parameters producing maximum joint strength were established at a peak weld current of 9 kA, where the electrode force and weld time are kept constant at 6 bars and 17 cycle, respectively.

Zhang (1997) found that obtained the stress intensity factors of resistance spot welds in order to correlate the fatigue behaviors of resistance spot welds in different types of specimens.

Marya et al. (2005) confirm that some minimum weld diameters could be recommended to prevent weld interfacial fracture.

Bayraktar et al. (2004) found that the mechanical behaviour of a resistance spot weld point in conventional tensile shear test depend on the geometrical factors such as morphology of weld point, sheet thickness, mechanical factors such as base metal behaviour, and also welding operations such as welding conditions, and test but depend very little on metallurgical factors such as structure of weld point and the chemical composition.

Hazlett et al. (2005) found that in his research, the crucial process parameters that appear to contribute significantly to the weld strength are the welding energy and time, the vibration frequency, the clamping pressure, and the size of the welding tip. It also appears that the strength of the weld is directly related to the bonded area. In the research, the commercial finite-element code ABAQUS was used to model the ultrasonically welded joints. Beside that, the failure mechanism and strength depend not only on the fracture parameters, but also on the size of the weld.

Tang et al. (2002) found that the electrode force is an important process parameter. The force functions to ensure electrical contact and retain weld nuggets from weld expulsion. Beside that, the weld strength with the increase forging force should decrease slightly. The weld quality can be improved by using a higher welding current when forging force is applied in the process.In the research also stated the increase forging force results in a slight negative influence on weld quality in terms of weld strength. Furthermore, high current can change many characteristics of a welding process, such as the temperature distribution in and around a weld nugget.

Santella et al. (1999) found that to make consistently good welds (using any process), two conditions must be met. First, an optimum set of welding parameters must be defined to produce the properties desired of the weld. Second, controls must be implemented to maintain process variables within the necessary ranges so that optimized welds can reproducibly be made. Furthermore, weldment properties depend on microstructure, and the welding parameters that produce optimized properties for one steel may not be optimized for a different one. This means that relying on physical attributes to specify resistance spot welding parameters is inherently unreliable. In this research also found that a large hardness gradient was found in the HAZ. A smaller hardness gradient was also observed within the weld nugget, which could be related to variations in the cooling rates within this region. The hardness gradients across the weldment are expected to influence the final properties of these resistance spot welds.