EXPERIMENTAL STUDY ON STRENGTH OF SPOT WELDED

Mohd Zaim Bin Din

A report in partial fulfillment
of the requirements for the award of the degree of
Bachelor of Mechanical Engineering

Faculty of Mechanical Engineering
Universiti Malaysia Pahang

NOVEMBER 2008
ACKNOWLEDGEMENTS

Alhamdulillah, finally I can finish my final year project. In preparing this paper, I have engaged with many people in helping me completing this project. First, I wish to express my sincere appreciation to my main thesis supervisor Mr Muhamad Bin Mat Noor, for encouragement, guidance, advices and motivation. Without his continued support and interest, this thesis would not have been the same as presented here.

Special gratitude to my father Din Bin Abdullah and my mother Nik Maznah Binti Nik Abd Rahman for their constant support and encouragement. It is also a pleasure to thank all my siblings for kindly sharing ideas and knowledge.

My sincere and utmost appreciation are most extends to all BMMians and all member was give supported. Their undivided love and support during tough times will never be forgotten. My fellow undergraduate students and others who have provided assistance at various occasions should be recognized for their support. Their views and tips are useful indeed.

Thank you all.
Abstract

In this research, the strength on the tensile-shear and coach peel type of welding joints in spot welding of 0.8 mm thicknesses mild steel sheets (JIS C314 SPCC-SD) was investigated. The welding joints were exposed to tensile shear and coach peel using tensile test machine, and the effect of welding time on coach peel strength and tensile shear strength was researched by using related period diagrams. A weld current period and weld time is 3 – 6 kA and 2 – 5 second respectively was selected during the welding process. In this experiment increasing welding times cause high heat input to weld zone and extending weld nugget, so the strength of joints increases mine while excessive heat energy input causes void and crack formations, partially spurt out of molten metal and so, the strength of joint decreases. The optimum parameter for tensile shear type is at 6 ampere (A) current and 4 second welds time (3847 N) and the highest strength for coach peel type is at 6 ampere current and 5 second welds time (889.5N). Finally the comparison result shown the higher strength of orientation using spot welding machine is tensile shear type.
Abstrak

Dalam kajian ini, kekuatan mengimpal pada sambungan jenis tarikan ricih dan ‘coach peel’ dalam kimpalan bintik untuk helaian keluli lembut ketebalan 0.8 mm jenis JIS C314 SPCC-SD telah disiasat. Kekuatan sambungan kimpalan pada tarikan ricih dan ‘coach peel’ didedahkan menggunakan mesin ujian tarikan, dan kesan masa kimpalan pada jenis sambungan dikaji menggunakan rajah bekaitan. Arus kimpalan dan masa kimpalan adalah 3 – 6 kA dan 2 – 5 saat masing-masing telah dipilih semasa proses ini. Dalam percubaan ini, kenaikan masa kimpalan menyebabkan banyak haba masuk kepada tempat kimpalan dan memanjangkan ‘nugget’ kimpalan, jadi kekuatan sambungan bertambah manakala tenaga haba yang masuk berlebihan menyebabkan kekosongan dan pembentukan keretakan serta sebahagian logam cair memancut keluar dari tempat kimpalan menyebabkan kekuatan sambungan berkurang. Parameter terbaik untuk tarikan ricih adalah pada arus 6 ampere (A) dan 4 saat masa kimpalan (3847 N) dan kekuatan tertinggi bagi ‘coach peel’ adalah pada arus 6 ampere (A) dan 5 saat kimpalan (889.5N). Akhirnya, perbezaan keputusan menunjukkan kekuatan paling tinggi menggunakan mesin kimpalan bintik adalah jenis tarikan ricih.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>TITLE PAGE</td>
<td></td>
<td>i</td>
</tr>
<tr>
<td>SUPERVISOR DECLARATION</td>
<td></td>
<td>ii</td>
</tr>
<tr>
<td>STUDENT DECLARATION</td>
<td></td>
<td>iii</td>
</tr>
<tr>
<td>DEDICATION</td>
<td></td>
<td>iv</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td></td>
<td>v</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td></td>
<td>vi</td>
</tr>
<tr>
<td>ABSTRAK</td>
<td></td>
<td>vii</td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td></td>
<td>viii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td></td>
<td>xii</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td></td>
<td>xiii</td>
</tr>
<tr>
<td>LIST OF SYMBOLS</td>
<td></td>
<td>xv</td>
</tr>
<tr>
<td>LIST OF ABBREVIATIONS</td>
<td></td>
<td>xvi</td>
</tr>
</tbody>
</table>

## 1 INTRODUCTION

1.1 Project background  

1.2 Problem Statements
1.3 Objectives

1.4 Project Scopes

2 LITERATURE REVIEW

2.1 Principle of Operation for Resistance Spot Welding

2.2 Parameters for Resistance Spot Welding

2.2.1 Weld time
2.2.2 Hold time
2.2.3 Squeeze time
2.2.4 Weld Current
2.2.5 Electrode Force

2.3 Material Selection

2.3.1 Mild Steel as a Work piece
2.3.2 Low alloy and medium carbon steel as a work piece

2.4 Tensile test

3 METHODOLOGY

3.1 Introduction

3.2 Literature Review
3.2.1 Internet 23
3.2.2 References Books 24
3.2.3 Discussion with Supervisor 24

3.3 Pilot testing 24

3.4 Selection of the resistance spot welding parameters 24

3.5 Experimental Procedure 25
  3.5.1 Minimum Welding Pitch 26
  3.5.2 Position of Spot Weld from the end of the Panel 27

3.6 Tensile Test Method 28

3.7 Data Collection 29

3.8 Comparison and Conclusion 29

4 RESULTS AND DISCUSSION

4.1 Introduction 30

4.2 Material specification 31

4.3 Tensile Test Result 32
  4.3.1 Effect of welding current in strength on Tensile Shear type 34
  4.3.2 Effect of welding current in strength of coach peel type 40
  4.4 Comparisons between tensile shear type and coach peel type base on strength 46
5 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion
   5.1.1 Welding Current and Time

5.2 Recommendation

REFERENCES
## LIST OF TABLES

<table>
<thead>
<tr>
<th>TABLE NO.</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Metals weldable by the spot welding</td>
</tr>
<tr>
<td>3.1</td>
<td>Spot welding positions</td>
</tr>
<tr>
<td>3.2</td>
<td>Position of Welding Spot from the End of Panel</td>
</tr>
<tr>
<td>4.1</td>
<td>Mechanical analysis for JIS C314 SPCC-SD</td>
</tr>
<tr>
<td>4.2</td>
<td>Chemical analysis for JIS C314 SPCC-SD</td>
</tr>
<tr>
<td>4.3.1</td>
<td>Effect of welding current in strength on Tensile Shear type</td>
</tr>
<tr>
<td>4.3</td>
<td>Data Collection for Current 3 ampere (A)</td>
</tr>
<tr>
<td>4.4</td>
<td>Data Collection for Current 4 ampere (A)</td>
</tr>
<tr>
<td>4.5</td>
<td>Data Collection for Current 5 ampere (A)</td>
</tr>
<tr>
<td>4.6</td>
<td>Data Collection for Current 6 ampere (A)</td>
</tr>
<tr>
<td>4.3.2</td>
<td>Effect of welding current in strength of coach peel type</td>
</tr>
<tr>
<td>4.7</td>
<td>Data Collection for Current 3 ampere (A)</td>
</tr>
<tr>
<td>4.8</td>
<td>Data Collection for Current 4 ampere (A)</td>
</tr>
<tr>
<td>4.9</td>
<td>Data Collection for Current 5 ampere (A)</td>
</tr>
<tr>
<td>4.10</td>
<td>Data Collection for Current 6 ampere (A)</td>
</tr>
</tbody>
</table>
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>FIGURE NO.</th>
<th>DESCRIPTION</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Resistance and Tig Spot Weld Comparison</td>
<td>4</td>
</tr>
<tr>
<td>2.2</td>
<td>Fundamental resistance welding machine circuits</td>
<td>5</td>
</tr>
<tr>
<td>2.3</td>
<td>Basic period of Spot welding</td>
<td>7</td>
</tr>
<tr>
<td>2.4</td>
<td>Spot welding time cycle</td>
<td>7</td>
</tr>
<tr>
<td>2.5</td>
<td>Electrode – work – piece interface resistance – R1 and R5; resistance of the work- pieces – R2 and R4; resistance in the interface between works – pieces- R3</td>
<td>8</td>
</tr>
<tr>
<td>2.6</td>
<td>(a) Manual portable spot welding gun</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>(b) Portable spot welding gun on robot (automatic)</td>
<td>10</td>
</tr>
<tr>
<td>2.7</td>
<td>Typical auto body locations in which spot welding are used during vehicle production</td>
<td>16</td>
</tr>
<tr>
<td>2.8</td>
<td>Tensile test machine</td>
<td>17</td>
</tr>
<tr>
<td>2.9</td>
<td>Stress - strain curve</td>
<td>18</td>
</tr>
<tr>
<td>2.10</td>
<td>Specimen under tensile load</td>
<td>18</td>
</tr>
<tr>
<td>3.1</td>
<td>Overall thesis flow chart</td>
<td>21</td>
</tr>
<tr>
<td>3.2</td>
<td>Experimental flow chart</td>
<td>22</td>
</tr>
<tr>
<td>3.3</td>
<td>tensile shear types and coach peel type (80 mm x 30 mm x 0.8 mm)</td>
<td>26</td>
</tr>
<tr>
<td>3.4</td>
<td>Minimum welding distances from the centre of the weld to</td>
<td></td>
</tr>
</tbody>
</table>
the centre of the next weld

3.5 The tensile test machine

4.1 example of collecting data using tensile test machine for tensile shear type

4.2 example of collecting data using tensile test machine for coach peel type

4.3 graph load (N) versus weld time (second) for tensile shear type

4.4 histogram maximum stress vs. weld time for tensile shear type

4.5 Breaking types observed in tensile shear type

4.6 graph load (N) versus weld time (second) for coach peel type

4.7 histogram maximum stress vs. weld time for coach peel type

4.8 Breaking types observed in coach peel type

4.9 Combination graph between coach peel and tensile shear

5.1 Current – time relationship

5.2 timing diagrams of current and force spot welding
LIST OF SYMBOLS

A - Ampere

H - Heat is generated in joules (watt-second)

I - Current (in amperes)

K - heat losses factor

N - Newton

R - Resistance (in ohms)

t - Time to current flow (in seconds)
# LIST OF ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AISI</td>
<td>American Iron Steel Institution</td>
</tr>
<tr>
<td>HAZ</td>
<td>heat affected zone</td>
</tr>
<tr>
<td>JIS</td>
<td>Japanese Industrial Standards</td>
</tr>
<tr>
<td>RSW</td>
<td>Resistance Spot Welding</td>
</tr>
<tr>
<td>SPCC</td>
<td>Cold Rolled Steel Sheet with Commercial Quality</td>
</tr>
<tr>
<td>ST</td>
<td>Squeeze time</td>
</tr>
<tr>
<td>WT</td>
<td>Weld time</td>
</tr>
</tbody>
</table>
CHAPTER 1

INTRODUCTION

1.1 Background

Spot welding is one of the oldest welding processes. It’s one form of resistance welding, which is a method of welding two or more metal sheets together without using any filler material by applying pressure and heat to the area to be welded. Resistance spot welding is a widely used joining process for fabricating sheet metal assemblies such as automobiles, truck cabins, rail vehicles and home applications due to its advantages in welding efficiency and suitability for automation. For example, a modern auto-body assembly needs 7000 to 12,000 spots of welding according to the size of a car, so the spot welding is an important process in auto-body assembly (Aslanlar et.al, 2008). Spot welding is an economical and primarily method for joining metals because its speed, precision, efficiency, and resulting cost reductions afforded by automated resistance spot welding are well documented and accepted, actually in automotive industry. The method is adaptable to high speed automation and is under strict cycle times.

The spot welding process is used to join sheet materials and uses shaped copper alloy electrode to apply pressure and convey the electrical current through the work pieces. In all forms of resistance welding, the parts are locally heated. The material between the electrodes yields and is squeezed together. It then melts, destroying the interface between the parts. The current is switched off and the "nugget" of molten materials solidifies forming the joint. The material has a higher electrical resistivity and lower thermal conductivity than the electrode used is suitable to choose such as steel.
because it making welding relatively easy. For another material such as aluminum, it’s electrical resistivity and thermal conductivity is closer to copper but the melting point for this material is lower than copper, make a welded is possible (Kalpakjian et.al, 2006).

In the spot welding it has some parameter to be considered. These parameters will affect the quality of the welds. The suitable combination of the spot welding parameter will produce strong joining and have a good quality of weld. Spot welding parameters include:

1) Electrode force
2) Diameter of the electrode contact surface
3) Squeeze time
4) Weld time
5) Hold time
6) Weld current

The strength of the joint in this process depends on the number and size of spot welded structure of the welds. The diameters size for spot-weld is range from 3 mm to 12.5 mm (Milleer, 2004). To investigate the strength of spot welds in terms of the specimen geometry, welding parameter, welding schedule, base metal strength, testing speed and testing configuration the tensile test method also can use to investigate the strength of the spot weld.

1.2 Problem statement

1. Failure in spot weld joining parts because of not suitable welding parameter setup and it cause a low strength.

2. The best design in term of orientation using spot weld joining need to be considered.
1.3 **Objective**

2. To Find out the strength of the joining process

3. To compare the quality joining with different orientation, different weld time and different weld current

1.4 **Project Scope**

This research is focus in spot welding method. This focus area is done based on the following aspect:

1. The toughness of the joining parts will be determined using tensile test.

2. Only one materials, one thickness and two orientations that will be use in this research

3. Base on mild steel material.
CHAPTER 2

LITERATURE RIVIEW

2.1 Principle of Operation for Resistance Spot Welding.

Resistance Spot Welding (RSW) is included in the group of resistance welding processes in which the heat is generated by passage of electric current through the bodies to be joined (Pires at.el.,). Spot welding process is different from another welding process such as arc welding because it’s not required filler metal or fluxes added to the weld area during the welding process (Cary , 2002). This spot welding process is unique because the weld nugget is form at between the surfaces of specimen. Figure 2.1 below show the comparison between nugget form for resistance spot weld and gas tungsten-arc weld (Resistance spot welding, 2005).

![Resistance and Tig Spot Weld Comparison](image)

**Figure 2.1** resistance and Tig Spot Weld Comparison

In resistance spot welding overlapping, two sheet of metal are joined by applying electric current and pressure in the zone to weld with copper electrodes (as shown in Figure 2.2). Spot welding operates based on four factors that are (Cary , 2002):
1. Amount of current that passes through the workpiece
2. The pressure applied to the workpiece by the electrode
3. The time current flows through the workpiece.
4. The area of the electrode tip contact with the workpiece.

Each spot welding is not performed on the same condition because of the alignment of sheets and electrodes as well as the surface condition. For that reason, a spot welding process needs the optimum process condition that can afford allowance in parametric values for good quality of welding. The optimum condition has to consider the amount and duration of electric current, the shape and material properties of electrode, the surface condition and alignment of sheets. Thus, the behavior of resistance spot welding process is extremely important to the quality of the entire welding structure (Resistance spot welding, 2005).

The displacement of the electrodes is also considered as an important feature during the resistance spot welding process due to its performance in the control of the quality of welding.

**FIGURE 2.2** Fundamental resistance welding machine circuits.
During the welding process, the amount of electric current is flow from the electrodes to the work pieces. The shape and size of the form weld are controlled by the size and contour of the electrode. This process is also depending to the welding time where the timer controls by four different steps (as shown in Figure 2.3 and figure 2.4) (Larry, 1999).

1. Squeeze time, or the time between the first application of electrode force and the first application of welding current
2. Weld time or the actual time where the current is flow through the work piece. The right or suitable amount of pressure was applied on the work piece is very important in order to obtain the quality of the weld.
3. Hold time, the period during which the electrode force is applied and the welding current is shut off.
4. Off period, or the time during which the electrodes are not contacting the work piece.

When electric current is flow through electrode tips to the separate work pieces of metal to be joined, the resistance of the base metal to electrical current flow causes heat and the heat is limited to the area which the tip of the electrode and weld area contacts. While the welding force is maintained, the heat is generating. In the holding stage (where the pressure is still maintained), the current is switched off and the nugget is cooled under the pressure (Cary, 2002).
The heat required for these resistance welding processes is produced by the resistance of the work pieces to an electric current passing through the material. Because of the short electric current path in the work and limited weld time, relatively high welding currents are required to develop the necessary welding heat. The amount of heat generated depends upon three factors: (1) the amperage, (2) the resistance of the conductor and (3) the duration of current. These three factors affect the heat generated as expressed in the formula below (Cary, 2002);

\[ H = I^2 R t \]
But for the practical purpose a factor $K$ (heat losses) should be included. Then the actual resistance welding is expressed by the Equation 2.1 (Cary, 2002):

$$ H = I^2 R t K $$  \hspace{1cm} 2.1

Where:

- $H$ = Heat is generated in joules (watt-second)
- $I$ = Current (in amperes)
- $R$ = Resistance (in ohms)
- $t$ = Time to current flow (in seconds)

**FIGURE 2.5**: Electrode – work – piece interface resistance – R1 and R5; resistance of the work- pieces – R2 and R4; resistance in the interface between works – pieces- R3

The secondary circuit of a resistance welding machine and the work being welded constitute a series of resistances. The total resistance of the current path affects the current magnitude. There are, in effect, at least five resistances connected in series in a weld that account for the temperature distribution and the sum of them is expressed as $R$ as shown in figure 2.5 above,
\[ R = R_1 + R_2 + R_3 + R_4 + R_5 \]

In the spot welding process there are six major points of resistance in the area. They are following:

1. The contact point between the electrode and the top work piece.
2. The top work piece.
3. The interface of the top and bottom work piece.
4. The bottom work piece.
5. The contact between the bottom work piece and the electrode.
6. Resistance of electrode tips.

The resistances of material are in series, and each point of resistance will retard current flow. The amount of resistance at point 3, the interface of the work pieces will depend to the heat transfer capabilities of the material, its electrical resistance, and the combined thickness of the materials at the weld joint. It is at this part of the circuit that the nugget of the weld is formed.

The heat generated depends basically on the electrical current and time being setup and on the electrical resistance of materials between electrodes. These inter-electrodes resistance is composed by five separated resistance, as indicated in Figure 2.5 (Pires et.al, 2005). Resistance at R1 and R5 are undesirable because they produce heating and consequently degradation of the electrodes. Resistance at R2 and R4 are the resistance of the work-pieces and they assume particular importance in the final period of the welds. To weld low resistive material is difficult because of reducing heat generate in the pieces. Resistance at R3 is important to determine the nugget formation, assuring the establishment of the weld (Pires et.al, 2005)

The nugget is a volume of melted material that forms in the interface of workpieces with a diameter related to sizes of those electrodes, as show in the figure 2.5. The penetration for nugget should be at least 20 % of the thinnest sheet member but not more
than 80% of the same thickness (Iwanitz et al., 2005). The passage of current initiates after the application of the electrode force will increase the temperature in the interface and developing a molten nugget. In the final part of the welding cycles plastics deformation occurs in the work-pieces. If current or pressure is too high, melted material can be expelled (splashed) to the atmosphere (Pires et al., 2005).

Resistance welding is used commonly for mass-production industries, where production run and consistent conditions are maintained. The resistance welding machine works automatically and less skill workers are needed. Resistance welding has the advantage of producing a high volume of work at a high speed, the product can be produced at high quality (Cary, 2002). Resistance spot welding also has been used in the repair industry, for example in Europe and Japan the resistance spot welding has been used in unibody collision repair industry for more than 25 years. This method is acceptable because resistance spot welding is ideal for welding many parts of unibody’s thin-gauge area that need good strength and no distortion (Larry, 1999). Figure 2.6 (a) shown the person conduct the manual portable spot welding gun and figure 2.6 (b) is Portable spot welding gun on robot (automatic).

**FIGURE 2.6:** (a) Manual portable spot welding gun  (b) Portable spot welding gun on robot (automatic).
2.2 Parameters for Resistance Spot Welding.

According to Joule’s law the welding parameter is time, pressure, current and electric resistances. In the electric resistance there are several parameters such as electrical receptivity of materials, quality of material surface to be weld and welding force (Pires et.al. 2005). The parameters that can be controlled in the welding machine are current, time and force (Pires et.al. 2005).

Generally, have a six important parameter in spot weld that is (spot welding parameter. 2008):

I. Electrode force
II. Diameter of the electrode contact surface
III. Squeeze time (ST)
IV. Weld time (WT)
V. Hold time
VI. Weld current.

For this spot weld project only four parameters are selected to do an experimental and going to be study, they are weld time, hold time, weld current and electrode force. To determination of appropriate welding parameters for spot welding is a very complex issue. A small change of one parameter will affect all the other parameters. This, and the fact that the contact surface of the electrode is gradually increasing, makes it difficult to design a welding parameter table, which shows the optimum welding parameters for different circumstances.

To get a better understanding of the parameters selected that going to be used for this project, there are several briefly explanation on the parameters;