EXPERIMENTAL STUDY ON STRENGTH

OF SPOT WELDED

MOHD ZAIM BIN DIN

UNIVERSITI MALAYSIA PAHANG

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

SUPERVISOR DECLARATION

“I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering”

Signature : ……………………………………..
Name of Supervisor : MR. MUHAMAD BIN MAT NOOR
Date : ……………………………………..

Signature : ....
Name of Panel : MR. MOHD RUZAIMI MAT REJAB
Position : Panel
Date : ....

STUDENT DECLARATION

I declare that this thesis entitled *"Experimental Study on Strength of Spot Welded"* is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....
Name : MOHD ZAIM BIN DIN
ID Number : MA05024
Date : ....

Dedicated, truthfully for support,
encouragement and always be there during hard times,
my beloved family.

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 ricihan 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

LIST OF TABLES

LIST OF FIGURES

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

AISI	-	American Iron Steel Institution
HAZ	-	heat affected zone
JIS	-	Japanese Industrial Standards
RSW	-	Resistance Spot Welding
SPCC	-	Cold Rolled Steel Sheet with Commercial Quality
ST	-	Squeeze time
WT	-	Weld time

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).

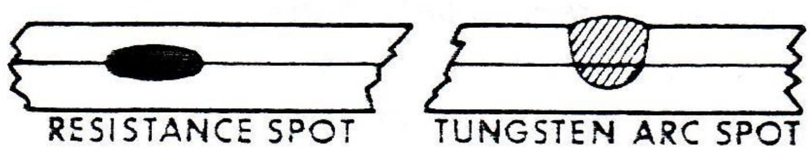


Figure 2.1 resistance and Tig Spot Weld Comparison

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 trough the work piece
2. The pressure applied to the work piece by the electrode
3. The time current flow trough the work piece.
4. The area of the electrode tip contact with the work piece.

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.

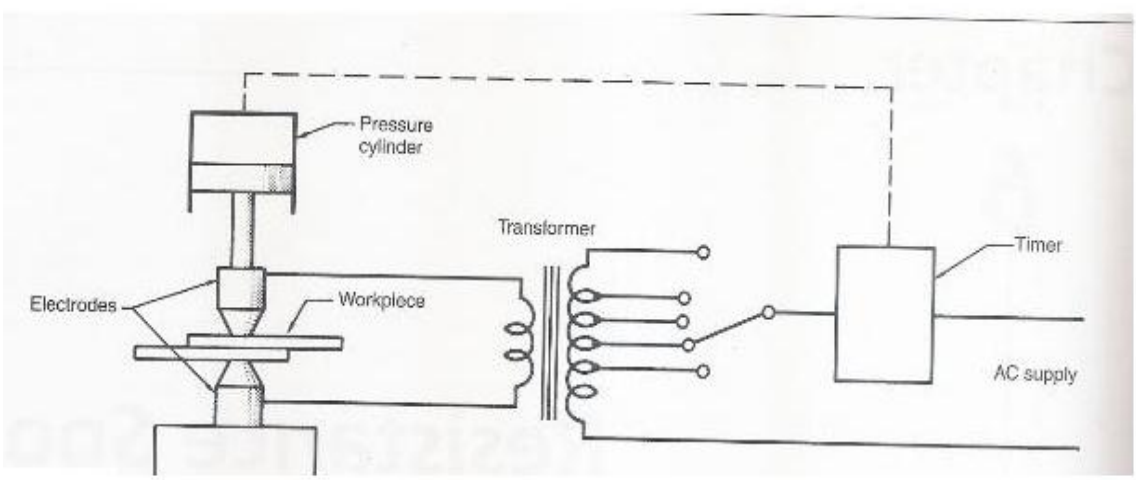


FIGURE 2.2 Fundamental resistance welding machine circuits.

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).

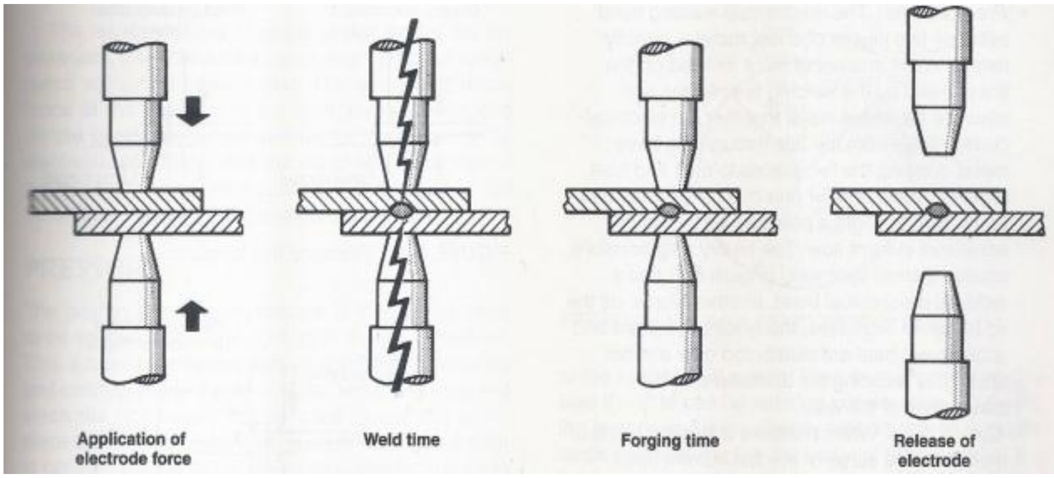


FIGURE 2.3: Basic period of Spot welding

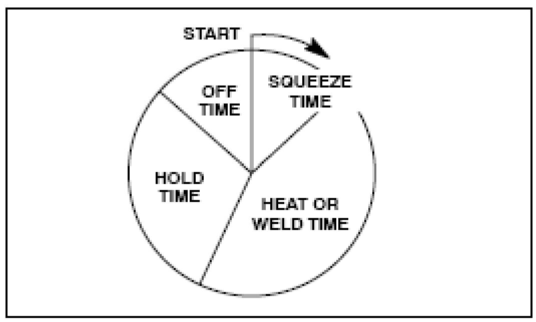


Figure 2.4: spot welding time cycle

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);

$$\mathbf{H} = \boldsymbol{I^2 R t} \qquad 2.0$$

But for the practical purpose a factor *K* (heat losses) should be include. Then the actual resistance welding is expressed by the Equation 2.1 (Cary , 2002):

$$\mathbf{H} = \boldsymbol{I^2 R t K} \qquad 2.1$$

Where:

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

I = Current (in amperes)

R = Resistance (in ohms)

t = Time to current flow (in seconds)

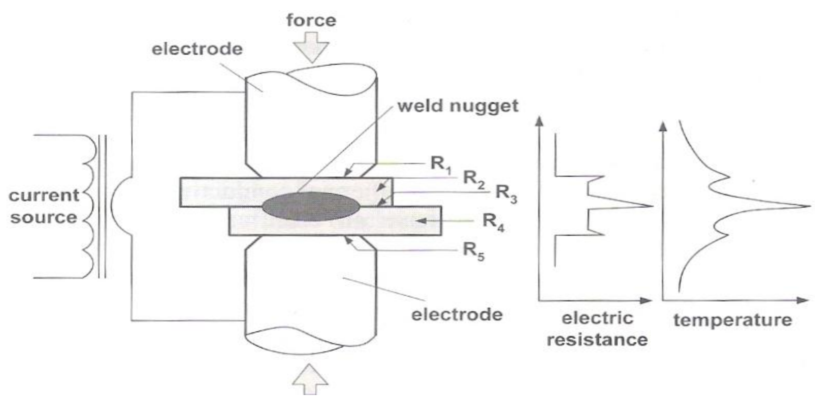


FIGURE 2.5: Electrode – work – piece interface resistance – R1 and R5; resistance of the work- pieces – R2 and R4; resistance in the interface between works – pieces- R3

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 point of resistance in the area. They are following:

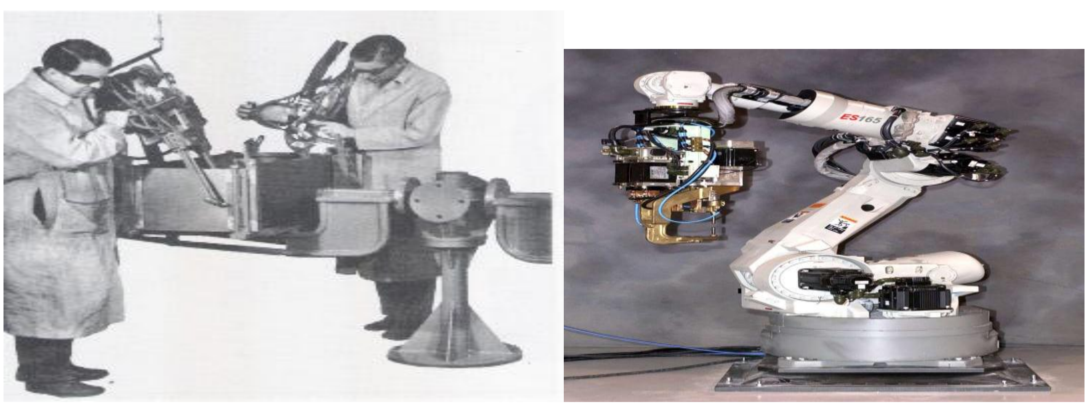
1. The contact point between the electrode and the top work piece.
2. The top work piece
3. The interface of the top and bottom work piece.
4. The bottom work piece.
5. The contact between the bottom work piece and the electrode.
6. Resistance of electrode tips.

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 work-pieces 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 expulsed (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).



(a) (b)

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;

i. Weld time

Weld time is the time during which welding current is applied to the metal sheets. The weld time is measured and adjusted in cycles of line voltage as are all timing functions. Most of the processes that using resistance spot welding is done in very short time. One cycle is 1/50 of a second in a 50 Hz power system (Pires et.al, 2005). It is difficult to determine the exact value of the optimum weld time because of a few uncertainties such as :

- Weld time should be as short as possible.
- The weld current should give the best weld quality as possible.
- The weld parameters should be chosen to give as little wearing of the electrodes as possible. (Often this means a short weld time.)
- The weld time shall cause the nugget diameter to be big when welding thick sheets.
- The weld time might have to be adjusted to fit the welding equipment in case it does not fulfil the requirements for the weld current and the electrode force. (This means that a longer weld time may be needed.)
- The weld time shall cause the indentation due to the electrode to be as small as possible. (This is achieved by using a short weld time.)
- The weld time shall be adjusted to welding with automatic tip-dressing, where the size of the electrode contact surface can be kept at a constant value. (This means a shorter welding time.)

For sheets with a thickness more than 2 mm, the best way is to divide the weld time into a number of impulses to avoid the heat energy to increase. Using this method will produced a good-looking spot welds but the strength of the weld might be poor (spot welding parameter, 2008).

ii. Hold time

Hold time also know as cooling time is the time where after the welding, the current flow is stopped, the electrodes are still applied, and the melted portion begins to cool and forms a nugget .Hold time is necessary to allow the weld nugget to solidify before releasing the welded parts, but it must not be to long as this may cause the heat in the weld spot to spread to the electrode and heat it (Larry, 1999). The electrode will then get more exposed to wear. Further, if the hold time is too long and the carbon content of the material is high (more than 0.1%), there is a risk the weld will become brittle. For welding galvanized carbon steel a longer hold time is recommended (spot welding parameter, 2008).

iii. Squeeze time

squeeze time (ST) is use to control the electrode tong to set enough time to close and apply full pressure to the work piece before the weld amperage start to go through to the work piece. Squeeze time is beginning when the remote foot or start switch is pressed.

iv. Weld Current

The amount of weld current is controlled by two things

1. The setting of the transformer tap switch determines the maximum amount of weld current available.
2. The percent of current control determines the percent of the available current to be used for making the weld.

Generally low percent current settings are not recommended as this may impair the quality of the weld. The weld current should be kept as low as possible. When determining the current to be used, the current is steadily increased until weld spatter occurs between the metal sheets. This indicates that the correct weld current has been reached. The temperature rises rapidly at the joined portion of the metal where the resistance is greatest .If the weld time element is too long, the base metal in the joint can exceed the melting point(and possibly the boiling point) of the material.

v. Electrode Force

The purpose of the electrode force is to squeeze the metal sheet to be welded in intimate contact at the joining interface (Iwanitz F et.al, 2005). This requires a large electrode force because else the weld quality will not be good enough and the force must not be to large as it might cause other problems When the electrode force is increased the heat energy will decrease, a high pressure that exerted on the weld joint will decrease the resistance at the point of contact between the electrode tips and the parts surface (Larry, 1999). This means that the higher electrode force requires a higher weld current.

When weld current becomes too high, spatter will occur between electrodes and sheets. This will cause the electrodes to get stuck to the sheet and heavy pressure will cause small spot weld. In other words when the pressure increases, the electrical current and subsequent heat are transfer to a wider area, the penetration and area of the weld will reducing (Larry, 1999).

2.3 Material Selection

The material going to be selected for this study must be weldable material, have the thickness that can be welded and have the joint design. Most of the common metals can be welded using the resistance welding process (Table 2.1).The weldability of the metals is determined by three factors that are resistivity, thermal conductivity and melting temperature (Cary. 2002).

TABLE 2.1: Metals weldable by the spot welding.

Metal	Weldability	Weldability Rating
Aluminum	Weldable	0.75–2+
Magnesium	Weldable	1.80
Inconel	Weldable	2+
Nickel	Weldable	2.15
Brass and bronze	Variable	0.5–10+
Monel	Weldable	2+
Precious metals	Variable	0.16–3.0
Low-carbon steel	Weldable	10+
Low-alloy steel	Weldable	10+
High- and medium-carbon steel	Possible	10+
Stainless steel	Weldable	35+
Titanium	Weldable	50+

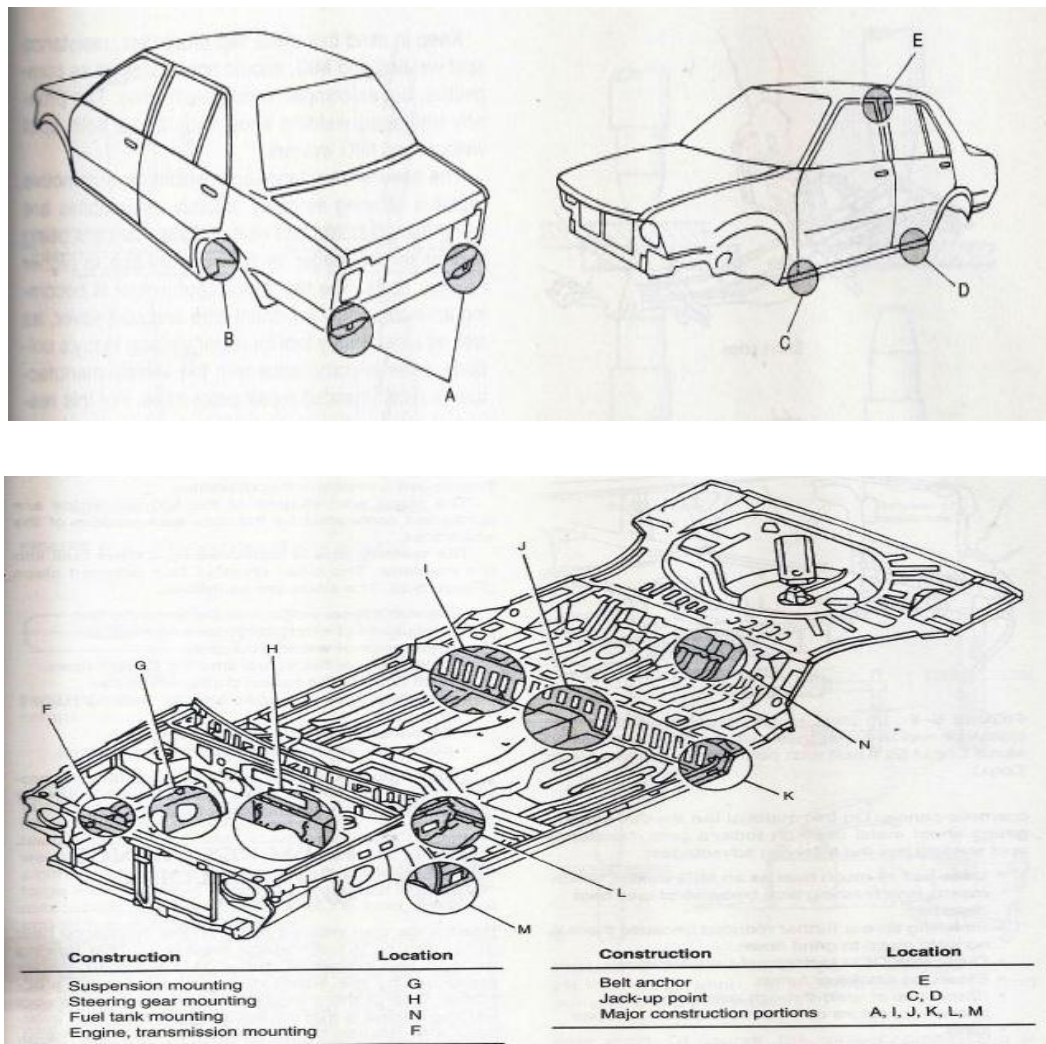
The material that has low thermal conductivity, high resistance to current flow and with a relatively low melting temperature is easy to weld (Cary. 2002).

2.3.1 Mild Steel as a Work piece

Mild steel or low carbon steels the largest percentage of material welded with the resistance spot welding process. Low carbon steel includes those in the AISI series C-1008 to C-1025. Carbon range from 0.10% to 0.25%, manganese range from 0.25% to 1.5%, phosphorus is 0.40% maximum, and sulfur is 0.50% maximum. Steel in this range are most widely used for industrial fabrication and construction (Cary. 2002).All low-carbon steels are readily weldable with the process if proper equipment and procedures are used. The carbon steels have a tendency to develop hard, brittle welds as the carbon content increases if proper post-heating procedures are not used. Quick quenching of the weld, where the nuggets cools rapidly, increases the probability of hard, brittle micro-structure in the weld (Resistance Spot Welding . 2005).

The presence of the carbon makes the steel stronger and harder than pure iron. The higher the percentage of carbon, the harder the steel becomes. Low Carbon steel typical uses are in automobile body panels, tin plate, and wire products. The disadvantages of low carbon steels is the poor corrosion resistance, they should not be used in a corrosive environment unless some form of protective coating is used.

The low carbon or "mild" steel is applied in the automotive structural application for many years (figure 2.7). The mild steel also used for the unibody collision repair for the car body (Larry. 1999).



FIGRUE 2.7: Typical auto body locations in which spot welding are used during vehicle production**.**

2.3.2 Low alloy and medium carbon steel as a work piece

The medium carbon steel includes those in the AISI series C-1030 to C-1050. The composition is similar to low carbon steel, except that the carbon range from 0.25% to 0.50% and the manganese from 0.60% to 1.65% (Cary, 2002). This material has a higher resistance factor compare to mild or low carbon steel. The current requirements for this material are slightly lower. Time and temperature are more critical since metallurgical changes will be greater with these alloys. This material is more possibility of weld embrittlement then is with mild steel (Resistance Spot Welding. 2005).

The pressure for RSW are normally higher with these material because the additional compressive strength inherent in this material. It is good idea to use longer welding times when welding this alloy to retard the cooling rate and permit more ductile welds (Resistance Spot Welding. 2005).

2.4 Tensile test

Tensile test is used in determine the strength of the joining under stretch loading. In this study, various combinations of parameters are used and to determine which combination produced the strongest strength, the work pieces will be test using tensile test machine (Figure 2.8).

FIGURE 2.8: Tensile test machine

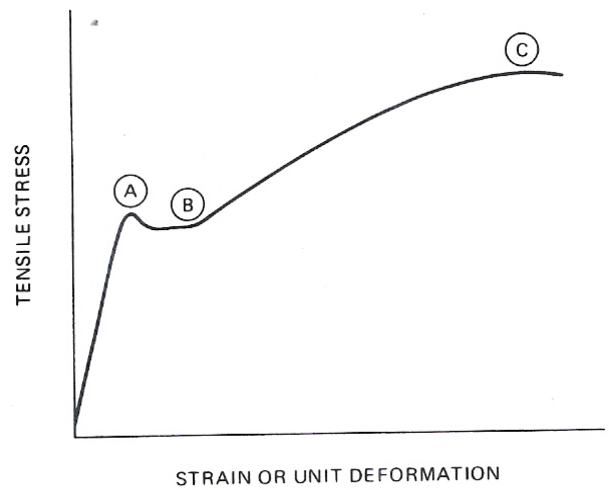


FIGURE 2.9 Stress - strain curve

Figure 2.9 above shows a typical curve for mild steels, in the testing operation (Figure 2.7), the load is increase gradually and the specimen will stretch in proportion to the tensile load. At point A, the specimen will elongate in the direct proportion to the load during the elastic portion. At this point, if the load is removing the specimen will come back to its original dimension. Yielding occurs from point A to B; this point is the point of plastic deformation. The specimen will not come back to its original dimension even the load is removed from point B. The specimen load will increase to point C where, point C is the ultimate strength of the material. At point C the specimen will break (Cary. 2002).

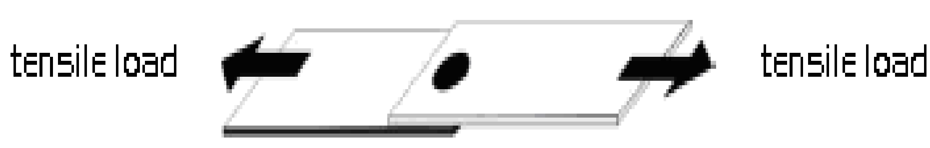


FIGURE 2.10: Specimen under tensile load

In this study, two plate of work pieces will be joint using resistance spot welding, the work pieces is then testing using the tensile test machine to get their strength. Figure 2.10 are show the load is applied to the specimen to check their strength of the weld join using tensile test machine. The testing is repeated using other resistance welding parameters and other design the weld joins.

CHAPTER 3

METHODOLOGY

3.1 Introduction

Methodology means a method to running the process. That means how the project must be do until this project is done. This chapter will be discussing about the methodology of the project. From this chapter, the flow chart of project has been follow to gain a successful result. Although this flow chart looks simple but it can guide clearly about the step must be follow, and refer to the flow chart (figure 3.1), had a 7 continued steps must be follow until finish the project. For experiment joining process, the flow chart in figure 3.2 showed the step of this process.

Generally, this project involved cutting the specimen, join the specimen using spot welding machine, testing their strength and finally analysis the data. First, design and cut specimen follow the dimension. Then join two sheet of metal using spot weld follow the orientation. For tensile strength test, the sample of sheet was testing after joining. Tensile will be focused on endurance limit to determine maximum force and maximum stress required to separate the joining material. The data was collected and the result will be analyzed.

Flow Chart

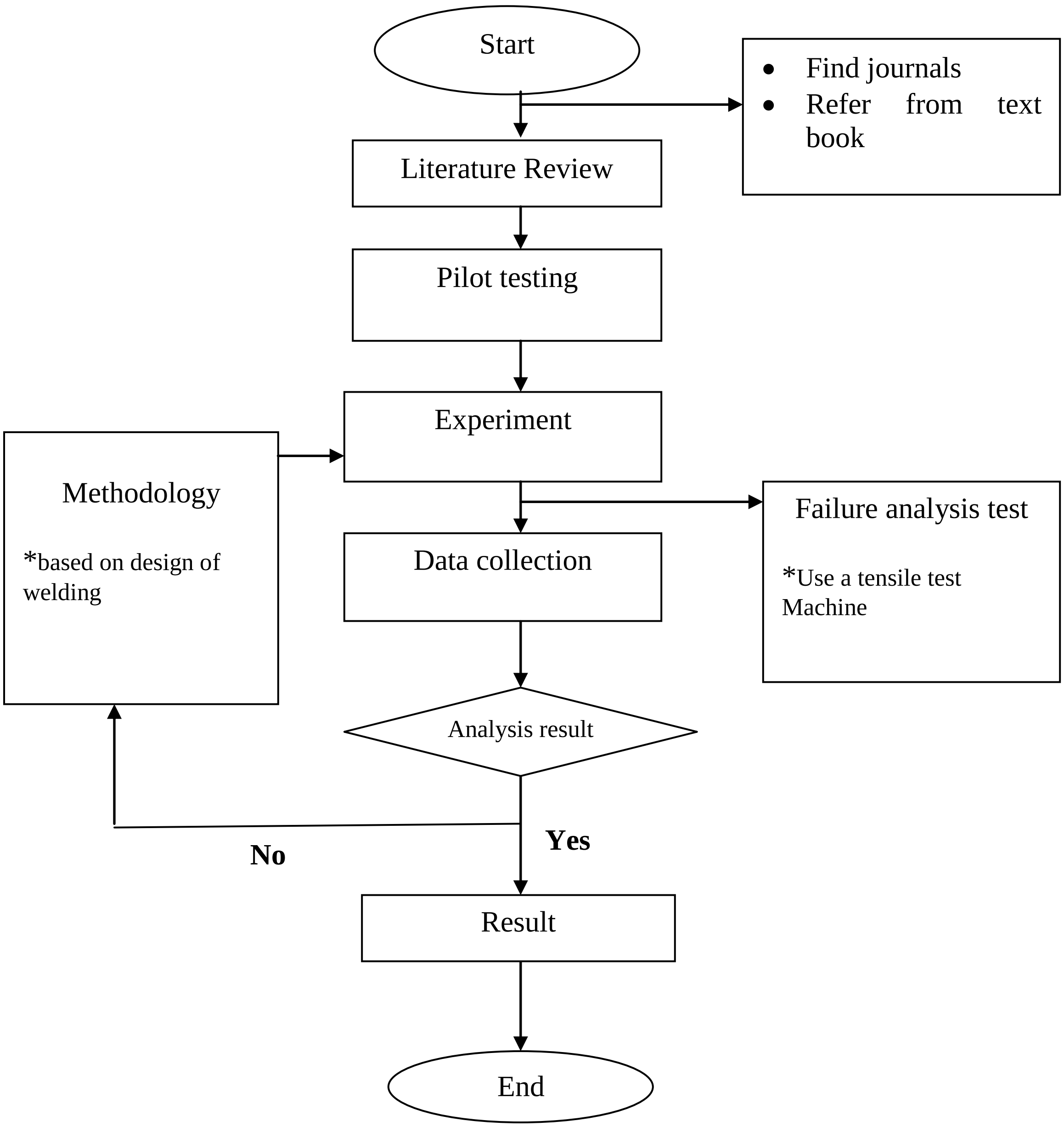


FIGURE 3.1 Overall thesis flow chart

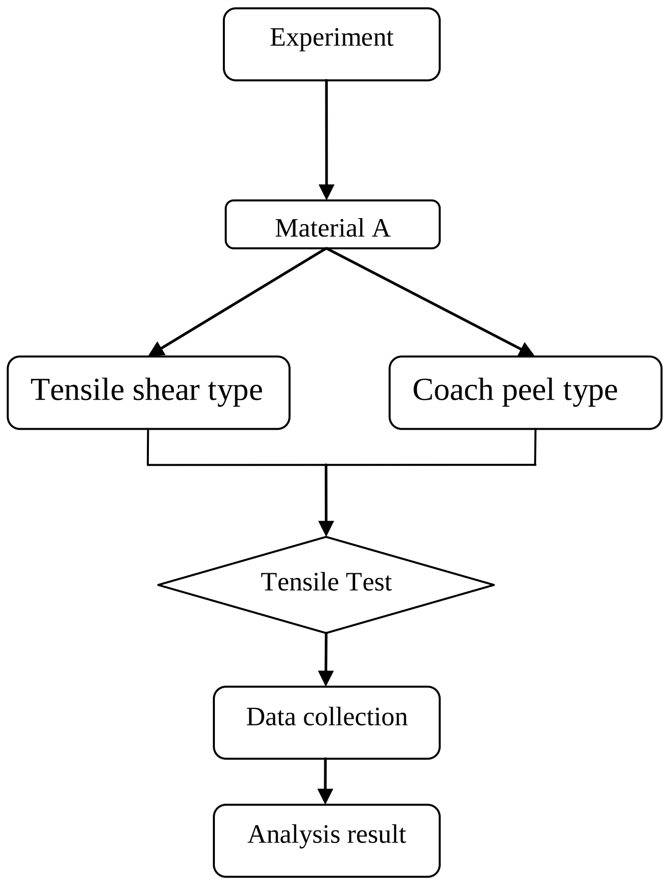


Figure 3.2 Experimental flow chart

3.2 Literature Review

To start this project, the most important is to understand the title of the project which is investigation the tensile force of spot welding using the different types of orientation, different current supply and different weld time when the experimental is running. The scope and the objective of this project also the important thing to consider and comprehend properly. So, in order to get the correct and precise information to complete this project it is important to get the right source of information in doing the literature review. That information which gets from the certain source must be accurate and useful to this project. There are the certain methods to get the information in order to complete the literature review.

I. Surfing the internet

II. Books

III. Discussion with supervisor

3.2.1 Internet

Internet is the one of the most important source to complete this research. It became the main source to find the information about the spot weld and procedure to testing and find their tensile force to get their strength. But not all the information from the internet is believable and can add such a reference. That's why the majority the information is getting from internet journal such as science direct journal. The internet journal is most efficient because the source is come from person do the experiment to prove their research.

3.2.2 References Books

The information and knowledge about the spot welding process also getting from the reference books. The process to test the specimen also can get from book. This information getting is believable because the books written by professional person such as professor outstanding researcher. Much knowledge can get from book, because many people do the researcher and write their book as a reference.

3.2.3 Discussion with Supervisor

Even the information is getting from the internet and the books is enough; discussion with the supervisor also important to make sure that the information which had gathered from the books and the internet is correct and useful to the project. Correct information is important because valid data come from the accurate information. Furthermore with the discussion can generate new ideas and exchange of thought about the research so that the title of the research can be more clear and understandable.

3.3 Pilot testing

Pilot testing is done in order test the equipment and the material to be weld. The pilot testing is also important to make sure the parameters that going to use is reasonable and either the spot welding machine can be adjustable according to parameters to be studied before the parameter is choose. It because, if the parameter is not suitable with material, it can damage the specimen and also can damage the electrode spot welding machine,

3.4 Selection of the resistance spot welding parameters

In this study machining parameters was setup follow the thickness of material chosen before the experiment can run. The thickness was chosen is 0.8mm. Machining parameters is parameters for the resistance spot welding. Two parameters are selected for the purpose of study. These two parameters are weld time and weld current. The electrode force and hold time is constant where the squeeze time is maintain to 1cycle.

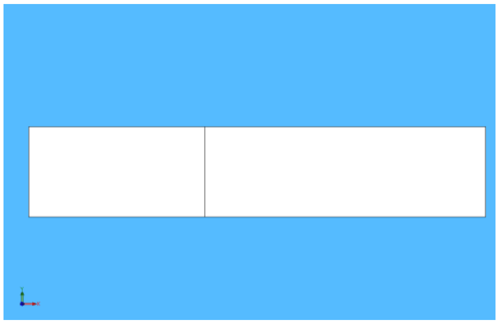
The purpose of the electrode force is to squeeze the metal sheets to be joined together. It requires a large electrode force if the weld quality will not be good enough; the electrode force is measured in Newton (N). Weld time is the time during which welding current is applied to the metal sheets. The weld time is measured and adjusted in cycles (one cycles = 1/60) (Larry, 1999) of line voltage as are all timing functions. Hold time is the time, after the welding, when the electrodes are still applied to the sheet to chill the weld and measured in cycles (one cycles = 1/60) (Larry, 1999). Hold time is necessary to allow the weld nugget to solidify before releasing the welded parts, but it must not be to long as this may cause the heat in the weld spot to spread to the electrode and heat it. The weld current is the current in the welding circuit during the making of a weld and be measured in ampere (A). The weld current chosen is 2A, 3A, 4A, 5A and 6A other while for the weld time, the time chosen is 2 cycles, 3 cycles, 4 cycles and 5 cycles. This two parameter setup is change until all weld current and weld time is setup and do an experiment.

3.5 Experimental Procedure

For this study, one type of mild steel with the thickness of 0.8 mm, 80mm length and 30mm width and two orientations (tensile shear and coach peel type) will be used as a work pieces. Each one specimen consists of two plate of mild steels was 80 mm x 30 mm x 0.8 mm (figure 3.3a) .There are eight of specimens that going to used for 0ne weld current setup for tensile shear and coach peel. Two plates are joint using the spot welding for every experiment. The specimen is then marked as the specimen A=2, t=2. The experiment is continued followed the current and weld time chosen. The other seven specimens are weld using the spot welding but with different combination of parameters that already setup. Then each of the specimens is marked using current supply setup and weld time setup. The marked such

I=i , t=j.   whete i= 2,3,4,5and 6

J=2,3,4, and 5



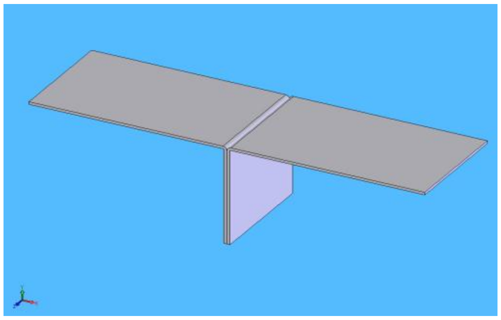


Figure 3.3 tensile shear types and coach peel type (80 mm x 30 mm x 0.8 mm)

3.5.1 Minimum Welding Pitch

The strength of the single spot welds in is determined by the spot weld pitch (distance between the welds) and the edge distance (distance from the spot to the panel edge) .The bond between the panels become stronger as the welds pitch is shortened. However, there is limit between new spot weld and previous one if pass the limit, shortening of the pitch will make no point because the current will flow to the spots that already welded. The diversion of the reactive current (Figure 3.4) will increase as the number of spot welds increase. The diverted current does not raise the temperature at the welds. So the position of the weld must be outside the reactive current diversion. Refer Table 3.1 (Larry, 1999).

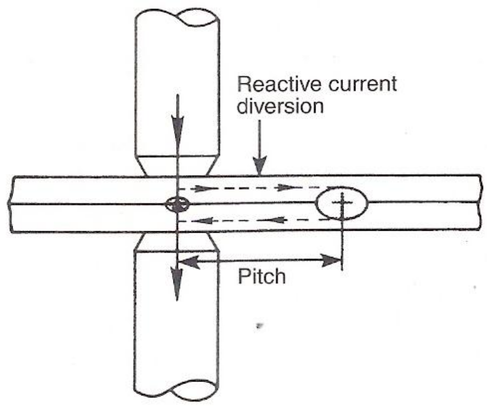
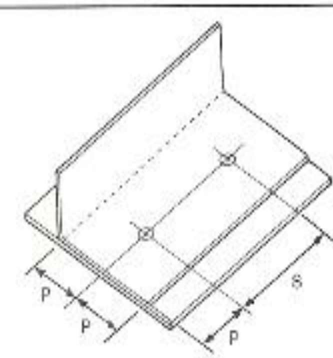


FIGURE 3.4 Minimum welding distances from the centre of the weld to the centre of the next weld

TABLE 3.1 Spot welding positions

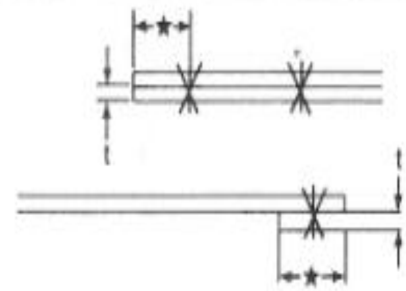
Panel Thickness	Pitch (S)	Edge Distance (P)
1/64"	7/16" or more	13/64" or more
1/32"	9/16" or more	13/64" or more
Less than 3/64"	11/16" or more	1/4" or more
3/64"	7/8" or more	9/32" or more
1/16"	1-9/64" or more	5/16" or more



3.5.2 Position of Spot Weld from the end of the Panel

The spot welds will not have sufficient strength id the edge distance is insufficient. The proper position of the spot welds from the end of the panel is shown in Table 3.2 (Larry, 1999).

TABLE 3.2 Position of Welding Spot from the End of Panel

Thickness (t)	Minimum pitch (★)	
1/64"	7/6" or over	
1/32"	7/6" or over	
Less than 3/64"	15/32" or over	
3/64"	9/16" or over	
1/16"	5/8" or over	
5/64"	11/16" or over	

3.6 Tensile Test Method

The specimen is then being test using the tensile test. The tensile load is applied until the specimen is break. The tensile load is then recorded. This method is done to investigate the strength of spot weld joining. All experiment must be run using this test to get their strength data.

Figure 3.5: The tensile test machine

3.7 Data Collection

This is one of the most important steps in the research because every data that been collected must be accurate and valid for the research. The process of collection data is done while doing the tensile test. For every test, four times reading will take for each specimen welding process.

3.8 Comparison and Conclusion

After the test and investigation had finished, the data will be collected and will be analyzed in order to get the best result. Comparison method will be done between the different parameter setup and different orientation. Each of the process will be analyzed based on the result from tensile test. The discussion based on the scope and the objective of this investigation.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

In this chapter the result from the testing using tensile test machine will be assessed and also strength properties of the specimen from spot welding joining for different type of orientation and different parameter setup will be study. Increasing welding times cause high input to weld zone and extending weld nugget, so the strength of the joining increase. The result from the tensile testing will be compared between results from the literature review.

The result of tensile test for different type of orientation and different parameter setup using spot weld process will be shown in figure below. For the evaluation of tensile strength of the specimen, the specimen with combination from 0.8mm cold roll steel are prepared and the tensile test is conducted. The data is analyzed and the load versus weld time relationship being shown in the figure.

4.2 Material specification

For this research, the material choosing to make a spot weld is JIS C314 SPCC-SD. This material is categories as low carbon steel. The condition this material is Cold Rolled SD cool Finish. Table below show the characteristic of this material based on mechanical analysis and chemical analysis.

Table 4.1 Mechanical analysis for JIS C314 SPCC-SD

Mechanical analysis	Yield strength (N/mm^2)	Tensile Strength (N/mm^2)	Elongation (%)	Hardness (%)
	239	358	42	55

Table above (figure 4.1) show the data of mechanical analysis for material using in this research. From the mechanical analysis for this table, the values of yield strength and tensile strength is 239 N/mm^2 and 358 N/mm^2 respectively. Other while for the elongation is 42% and hardness is 55%.

Table 4.2 Chemical analysis for JIS C314 SPCC-SD

Chemical Analysis (%)	C	Si	Mn	P	S
	0.15	0.10	0.60	0.50	0.50

Table 4.2 is a data for chemical process for the material. It shown the values of element type contained in this material type. Because this material is in mild steel or low carbon steel, the value for carbon content is lower, only o.i5%. To know the categories of steel is in low carbon steel, the value of carbon content in material is important to know because the value for carbon in this material is range from 0.10% to 0.25%,

manganese range from 0.25% to 1.5%, phosphorus is 0.40% maximum, and sulfur is 0.50% maximum. From the table, all the values are content in the criteria of mild steel.

4.3 Tensile Test Result

The specimen were join using spot welding for different type of orientation and different setup of parameter were tested to study the strength of spot weld joining observe the tensile properties as shown by the load (N) versus number of weld time to failure relationship.

The high strength of joining mild steel specimen was defined to get their parameter setup to use in weld joint using 0.8 mm thickness. The data is getter from tensile test machine and the graph is plot follow the increasing or decreasing rate of data. The data collect for both orientations is shown in table below:

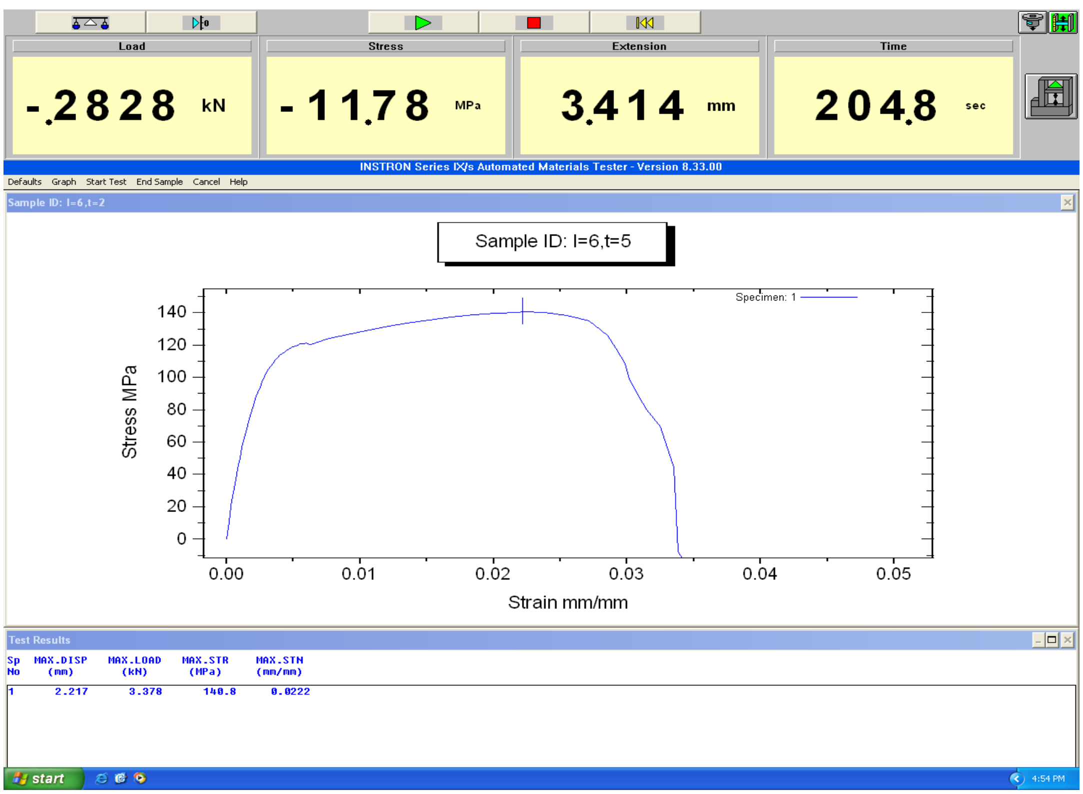


Figure 4.1 example of collecting data using tensile test machine for tensile shear type

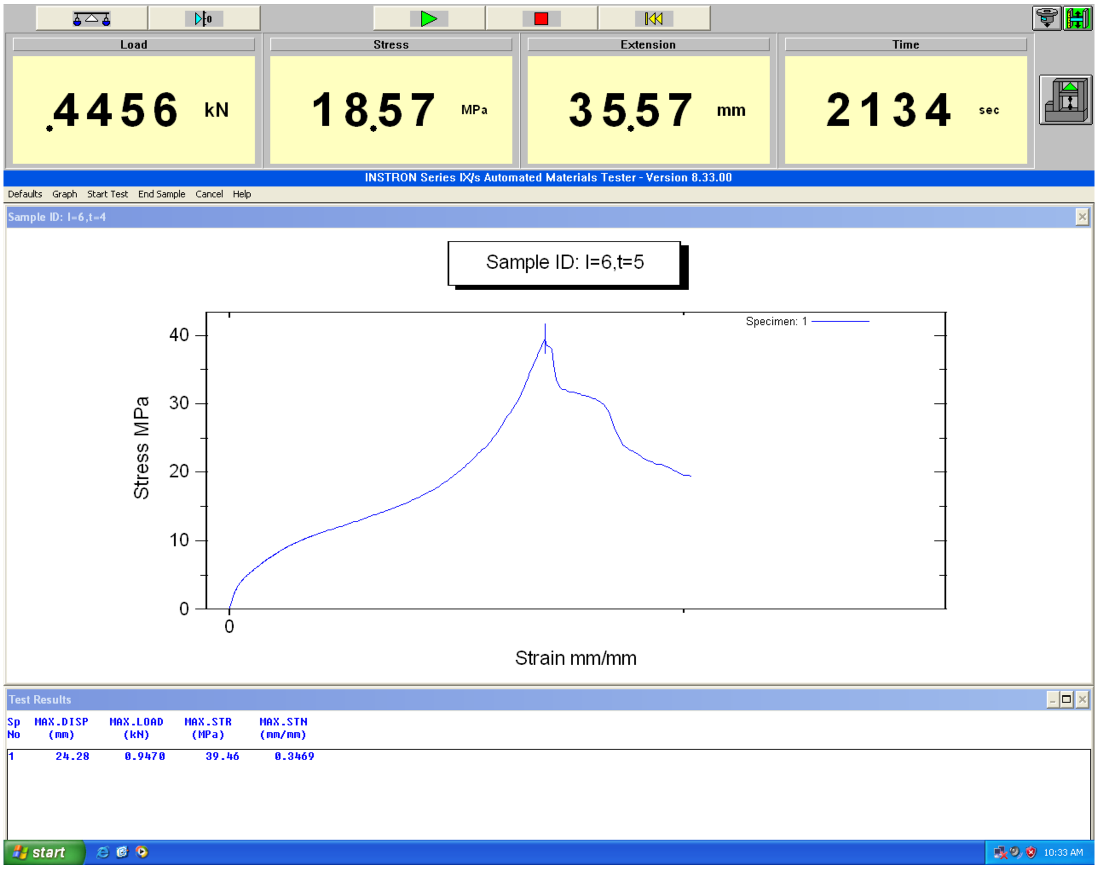


Figure 4.2 example of collecting data using tensile test machine for coach peel type

Figure 4.1 and figure 4.2 is an example of data collecting using tensile shear machine for tensile shear type and coach peel type respectively. The graph is increase for initially and after the specimen is separate the graph is decrease. From the theoretical, for the tensile shear test has a two phase occur when the specimen is elongation, which is elastic region and plastic region. After it reaches the plastic region, the specimen can't back to normal position again if the load is removed. The maximum load and maximum stress is collect at the maximum high of graph before it separate. The value of the maximum load and maximum stress is getting from average testing 2 specimens. After that the data is record in table for every specimen testing.

4.3.1 Effect of welding current in strength on Tensile Shear type

Table 4.3 Data Collection for Current: 3 ampere (A)

Weld time (second)	Max Load(N) 3A	Max Stress(MPa)	Max Strain (mm/mm)
2	277.5	11.563	0.0003
3	479.45	19.975	0.005
4	790.9	32.955	0.0008
5	1002.75	41.79	0.0011

Table 4.4 Data Collection for Current: 4 ampere (A)

Weld time (second)	Max Load(N) 4A	Max Stress(MPa)	Max Strain (mm/mm)
2	1156	48.18	0.0013
3	1470.5	61.27	0.0017
4	1844.5	76.87	0.0022
5	2569.5	107.1	0.0039

Table 4.5 Data Collection for Current: 5 ampere (A)

Weld time (second)	Max Load(N)	Max Stress(MPa)	Max Strain (mm/mm)
2	1978.5	82.43	0.0032
3	2402.5	100.1	0.0049
4	2487	103.65	0.004
5	2842.5	118.4	0.0057

Table 4.6 Data Collection for Current: 6 ampere (A)

Weld time (second)	Max Load(N) 6A	Max Stress(MPa)	Max Strain (mm/mm)
2	2964.5	123.5	0.0091
3	3120.5	126.35	0.0095
4	3847	160.25	0.0174
5	3301.5	137.6	0.0169

From the entire table above, it is shown that the results of the tensile shear type using tensile test machine. There have a several data was measured such as maximum load, maximum stress and maximum strain. For each table, have a one weld current setup and four weld time setup to get their strength of the welding. The data shown is the average of 2 times testing for every specimen.

After analyze the data, the graph for load versus weld time and the histogram for the maximum stress for tensile shear type is shown in figure 4.3 and 4.2 below.

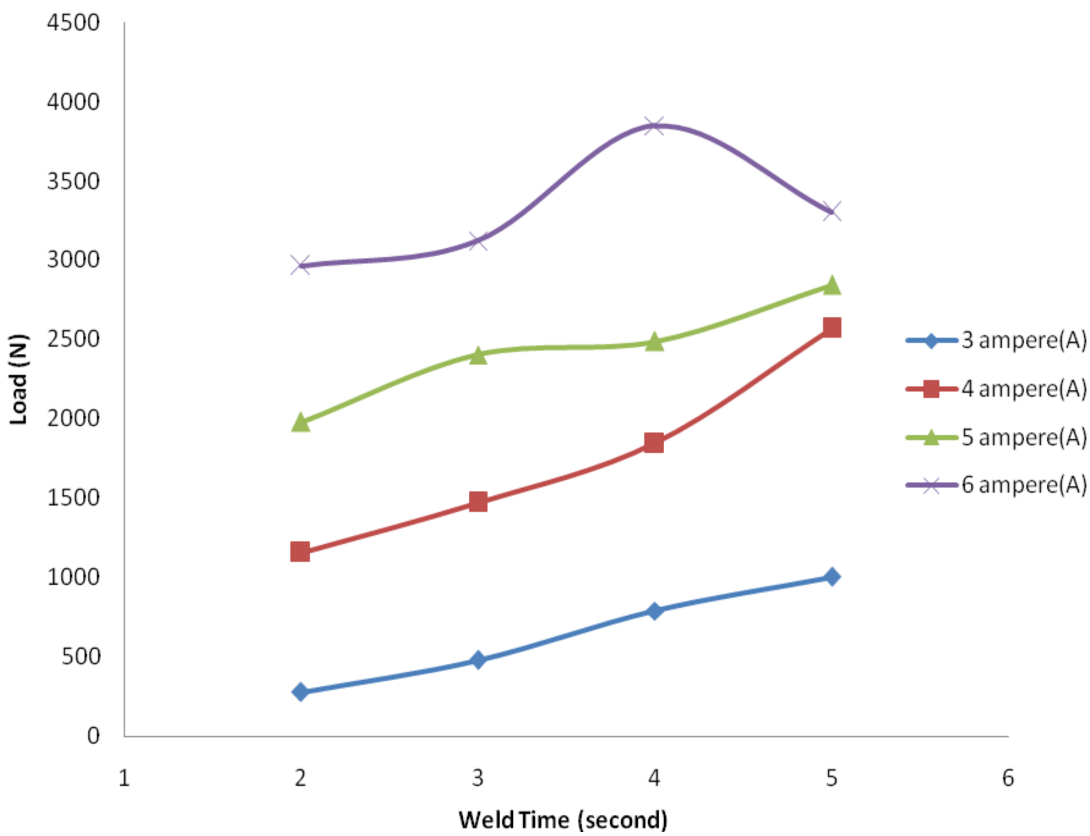


Figure 4.3 graph load (N) versus weld time (second) for tensile shear type

Figure 4.3 above shown that the graph plotted for relationship between loads (N) versus weld time (second). From the graph, it state clearly how the phase of graph plotted. For 3 ampere weld current, the graph is start with lower plotted at 2 second weld time where the value is 277.5 N for maximum load. For 3 second and 4 second weld time the graph is increase approximate to 500 N and 790.9 N respectively. Mine while for the 5 second weld time, the value for maximum load is highest, that is 1102.75 N. From this graph plotter, it shown that there is no optimum parameter setup for 3 ampere welds current because the data is still increasing.

For the 4 ampere (A) weld current, it still increased from 2 second to 5 second. It shows that, the parameter setup is not reaching the optimum parameter. To get the best joining using this weld current, the weld time must be increasing until the graph is decrease. So the optimum parameter is can measured at the highest graph plotter before it decreases. The lower value for the maximum load for this weld current is at 2 second and the highest maximum load is at 5 second with the value is 1156 and 2569.5 N respectively.

For the 5 ampere (A) weld current setup, the graph plotted is same with graph 3 ampere (A) and 4 ampere (A) where the values are still increased from 2 second to 5 second. But for the 6 ampere current using, the data is increasing for the 2 second, 3 second and 4 second, but for the 5 second the plotted is decrease. The value decrease is near 500 N for one cycles weld time changing. From this plotted, it show that the optimum parameter setup is at 6 ampere weld current and 4 second weld time. And after this optimum parameter, at 6 ampere and 5 second the graph is decrease because the current pass through the work piece in a long scale from the suitable setup make the structure change their properties and affects the structure of the specimen, make it come week.

From the reading, after the parameter setup is optimum and the parameter is still increase, it affects the structure of material, make the specimen void and crack formation and make the joining come week, also decrease their strength. The excessive heat supplied also make the partially spurt out of molten metal, once the cause make the joining week. So The theoretical is accepted for the maximum load is decreased after the welding parameter setup is exceed the optimum parameter setup at 6 ampere (A) for weld current and 4 second for weld time.

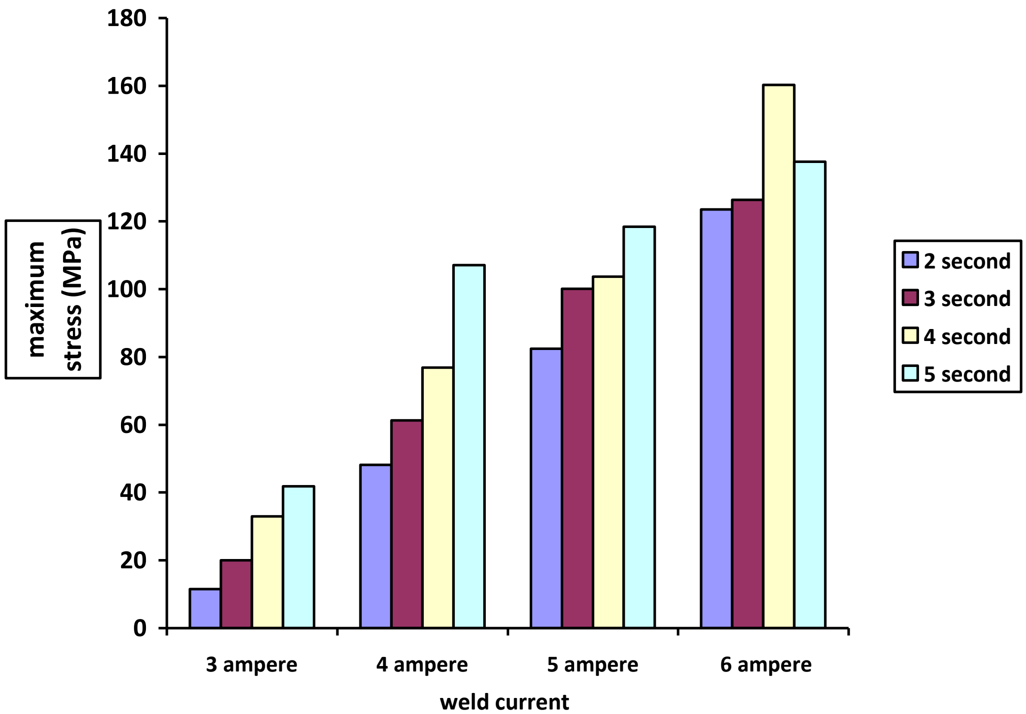


Figure 4.4 histogram maximum stress vs. weld time for tensile shear type

Histogram above showed the maximum stresses versus weld time for four weld current setup and four weld time setup. This histogram showed the increasing values of maximum stress corresponding to the increasing of weld time. The lower value for maximum stress for weld current is at 2 second and the higher is at 5 second for weld current setup is 3A, 4A and 5A. Where for the 6A weld current the lower value is at 2 second and the highest is at 4 second. For the 5 second the value is decreasing. This histogram data is like same with the graph plotted where the values is increase for 3 ampere, 4 ampere and 5 ampere weld current setup and for 6 ampere current, the data is increasing for 2 second until 4 second but decrease at 5 second. So, the optimum weld current and weld time for the highest values for maximum stress is same as the optimum parameter for the maximum load where the parameter setup is at 6 ampere (A) and 4 second. So the maximum load and maximum stress is directional to the weld time and weld current. If the weld current and weld time increase, the maximum load and maximum stress also increase.

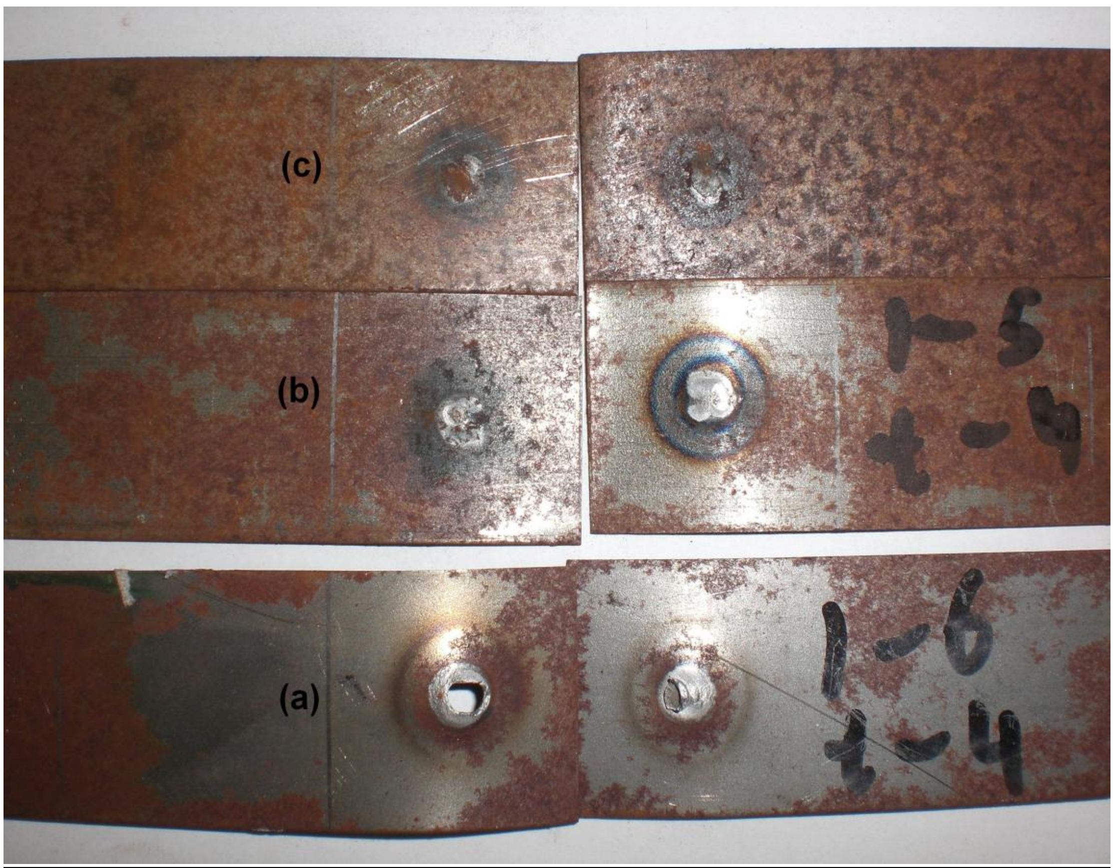


Figure 4.5 Breaking types observed in tensile shear type

Figure 4.5 show the type of breaking failure observed during the test using the tensile test machine. From testing for the tensile shear type joining, have three type of braking failure, there is separation, knotting and tearing breaking type. For sample (a) the breaking failure type is knotting, where the nugget is separate without damage the structure behind the nugget. The attraction of nugget makes a hole like a round. Because that the breaking type is name as knotting. This failure is occur when the nugget is strength than material specimen. For sample failure (a), the specimen is setup at an optimum parameter at 6 ampere (A) weld current and 4 second weld time.

For sample (b) and (c), the type failure occurs is separation. This failure type occurs when the joining is not enough strength, where the nugget is not getting enough heat energy to melt and join together. For specimen (b), it has a more strength from the specimen (c) where the heat affected zone is clearer from the specimen (c). It is acceptable because parameter setup for specimen (b) is higher than specimen (a). So the specimens (b) have more heat energy than specimen (c) to make a nugget in the joining process is having more strength than specimen (c).

If the failure type is compare with another testing, the strength of specimen can specified follow the type of breaking occur to the specimen when the tensile test is doing. When the specimen have a separation type breaking, the conclusion can make about this specimen type is it is have a low strength if compare to knotting breaking failure. Not all specimen have a separation and knotting breaking type, it is depends to parameter setup for welding process, if the joining is week, only a separation breaking is occur, but if the strength is high, the knotting or tearing breaking failure is occur.

4.3.2 Effect of welding current in strength of coach peel type

Table 4.7 Data Collection for Current: 3 ampere (A)

Weld time (second)	Max Load(N)	Max Stress(MPa)	Max Strain (mm/mm)
2	21.8	0.9077	0.0021
3	64.35	2.6825	0.0086
4	71.5	2.9785	0.00535
5	98.35	4.099	0.025

Table 4.8 Data Collection for Current: 4 ampere (A)

Weld time (second)	Max Load(N)	Max Stress(MPa)	Max Strain (mm/mm)
2	93.95	3.916	0.0103
3	115	4.7925	0.2265
4	117.55	4.8995	0.0215
5	310.75	3.4425	0.0149

Table 4.9 Data Collection for Current: 5 ampere (A)

Weld time (second)	Max Load(N)	Max Stress(MPa)	Max Strain (mm/mm)
2	264.85	11.035	0.166
3	551.85	22.99	0.2334
4	554.8	23.12	0.3672
5	826.4	34.435	0.3665

Table 4.10 Data Collection for Current: 6 ampere (A)

Weld time (second)	Max Load(N)	Max Stress(MPa)	Max Strain (mm/mm)
2	729.8	30.41	0.3472
3	838.6	34.94	0.3360
4	876.4	36.515	0.3372
5	889.5	37.065	0.3403

Table 4.7, 4.8, 4.9 and 4.10 above show the data for coach peel type using tensile Test machine. The entire table is same with the data table for tensile shear type. It start with 3 ampere until 6 ampere for weld current and 2 second to 5 second for weld time.

Figure 4.6 below shown the graph plotted for coach peel type data.

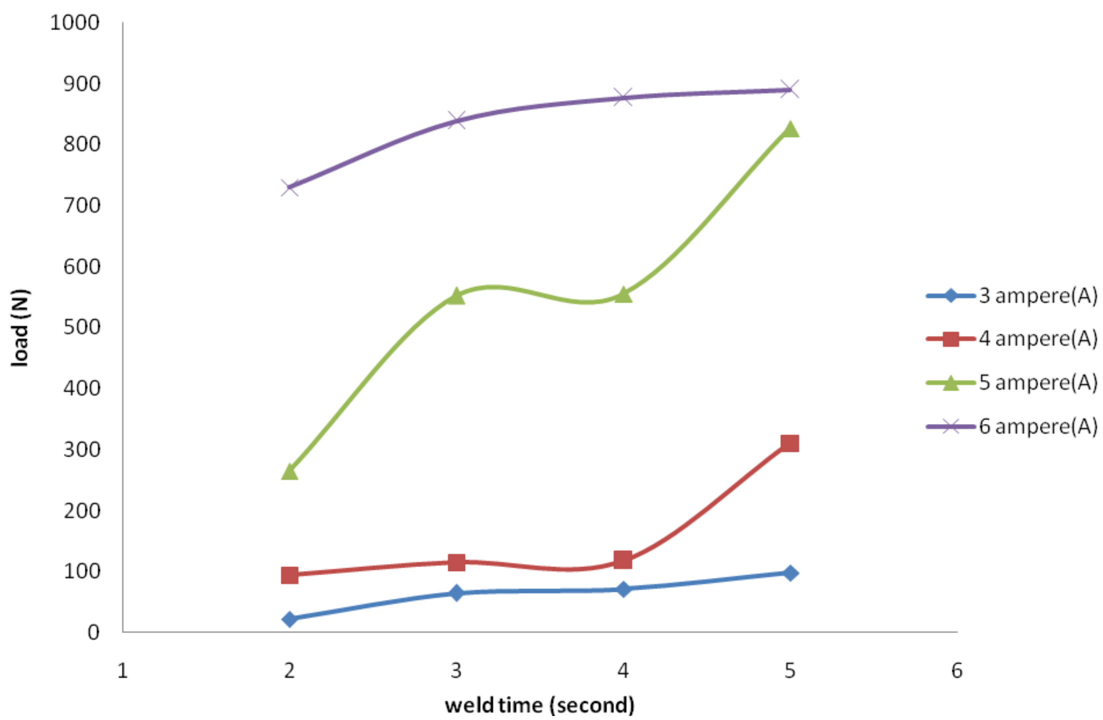


Figure 4.6 graph load (N) versus weld time (second) for coach peel type

From the graph in figure 4.6, have a four type of graph and for every type, have a four plotter data. The graph is start with the low value of strength at 3 ampere weld current and 2 second weld time. The value for maximum load is only 21.8 N. for the 3 second the value for maximum load is 64.35 N. mine while for the weld time at 4 second and 5 second the value is still increase, but the maximum load for this graph is not exceed 100 N. from this graph, it shown that the joining specimen for coach peel type using this parameter is not suitable because the value of maximum load is very low and the joining is known as a weaker joining.

For the second and third graph, using 4 ampere and 5 ampere current, the all graph plotted is increase start from 2 second to 5 second. But for 4 ampere, the increasing rate of maximum load for the weld time setup at 2 second, 3 second and 4 second is in small value. The value is 93.95 N, 115 N and 117.55 N respectively. This situation occurs may be about the effect of corrosion to the specimen when the welding process occurs or when the testing specimen using tensile test machine. As known, the corrosion is affecting the structure of material, make the material weak. But for the 5 second weld time, the value is increase in large amount about 200 N. for 5 ampere, the small increasing amount was plotted at 3 second to 4 second and from 4 second to 5 second the plotted is increasing large as in 2 second to 3 second.

For the 6 ampere weld current supply, all plotted data still increase, start from 2 second until 5 second. It shown that, using this parameter setup, the optimum parameter setup for this type is unknown.

For overall testing all parameter setup start from 3 ampere to 6 ampere for weld current and 2 second until 5 second for weld time using coach peel type specimen, not one from the setup is shown the optimum parameter to take as a best weld joining. To get the optimum parameter setup, the weld time should be increase until the value for maximum load is getter before it decreases.

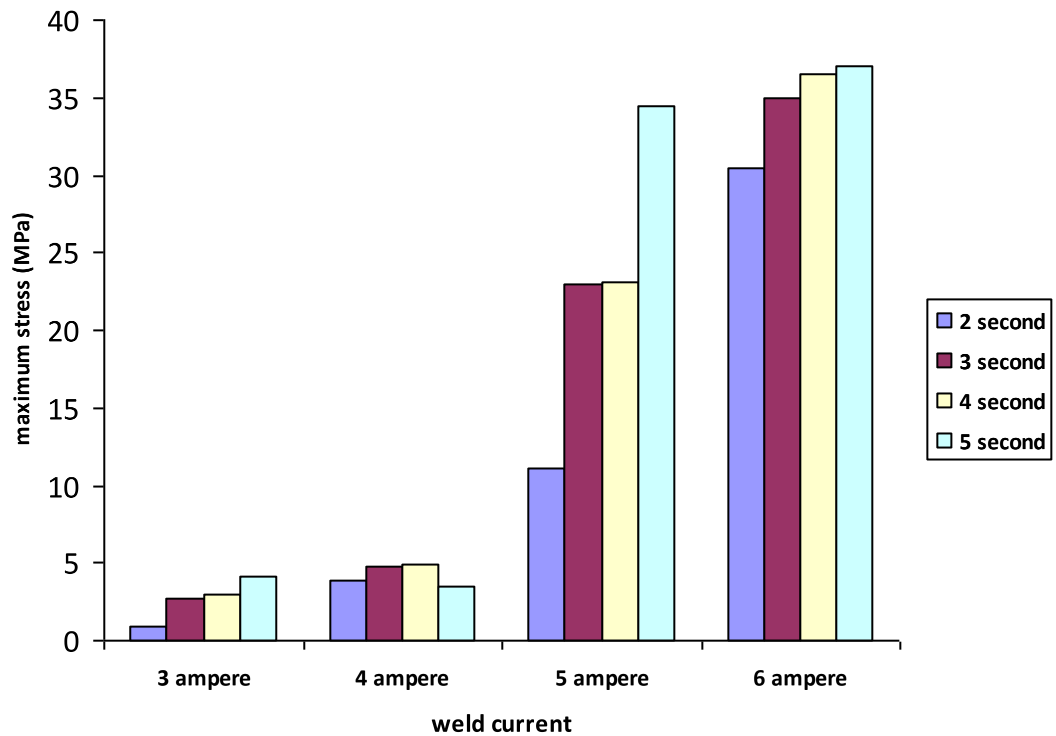


Figure 4.7 histogram maximum stress vs. weld time for coach peel type

In figure 4.7, this histogram showed the maximum stress for every weld current and weld time using for coach peel type. This chart is start in very low stresses for 3 ampere and 4 ampere. This is because the maximum load for this part is very low. It show that the specimen joining using this type is not suitable to use because it have a low strength and not save if the joining is doing to specimen. For chart in 3 ampere, it start with increase rate for all weld time setup, but for 4 ampere, the graph is start increased at the first three cycle then the graph is decrease for 5 second. Follow the tensile shear data in maximum stresses, the chart must increase according to the increasing maximum load in 5 second. This phenomenon occurs because of corrosion and effect the structure, make the material not have a high strength, or the data for the testing is wrong when the technical problem occur to the tensile test machine.

For the 5 ampere and 6 ampere, the chart is continuously increased until it reaches 5 second weld times. So the parameter setup at 5 ampere and 6 ampere using 5 second weld time is most suitable to use compare to the parameter setup at 3 ampere and 4 ampere. To get the better parameter setup and optimum parameter for a good and high quality of joining the weld time is must be increase until it reaches the high maximum stress because the maximum stress is directly proportional to the maximum load. If the maximum stress is increase, the maximum load also increases.

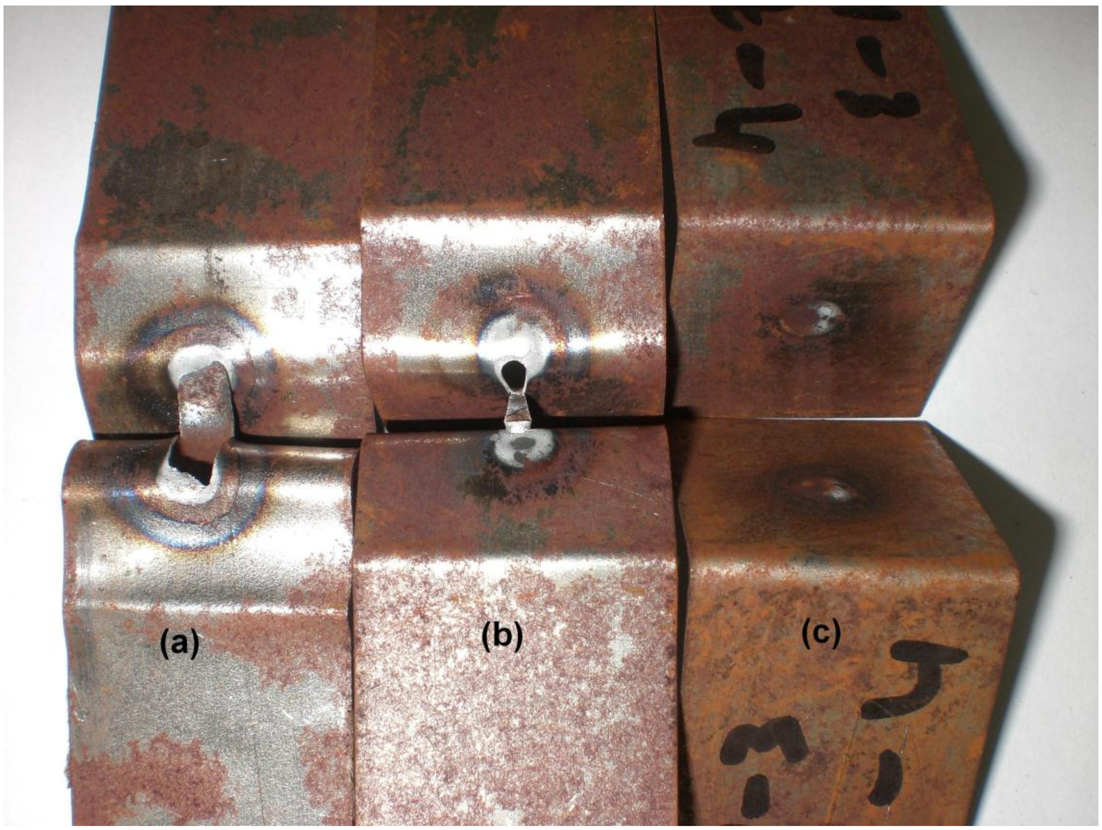


Figure 4.8 Breaking types observed in coach peel type

From figure 4.8 above, the picture is shown about the type of breaking failure occur in the specimen using tensile test machine. There have a three type of breaking failure is normally occur in testing specimen, but for coach peel type, only two braking is occur. The type of braking occur in this specimen is only separation and tearing.

For specimen (a) and (b) in figure 4.8 the breaking failure type is tearing type breaking. To known the tearing breaking type, the structure of hole is not round shape, but the shape like egg shaped. It also make a torn off detect to the specimen. For this coach peel type, it make a long time to separate but the tearing breaking failure is occur in many specimen with using 5 ampere and 6 ampere weld current. For the specimen (a) and (b), the parameter setup is at 6 ampere and 5 ampere respectively using 4 second weld time setup. From this picture, the conclusion can make is, the weld nugget is most strength to joining together to torn off the specimen but, it not enough strength to join together because the coach peel type shape make the joining strength make weak.

Then for specimen (c) (figure 4.8) the breaking failure type occurs is separation breaking type. It only separates without leave a hole at the specimen. For this type, it occur to the low strength of joining because the weld nugget is not meld perfectly make the joining between work piece have a low strength. To get the best joining, the weld time should be increase.

4.4 Comparisons between tensile shear type and coach peel type base on strength.

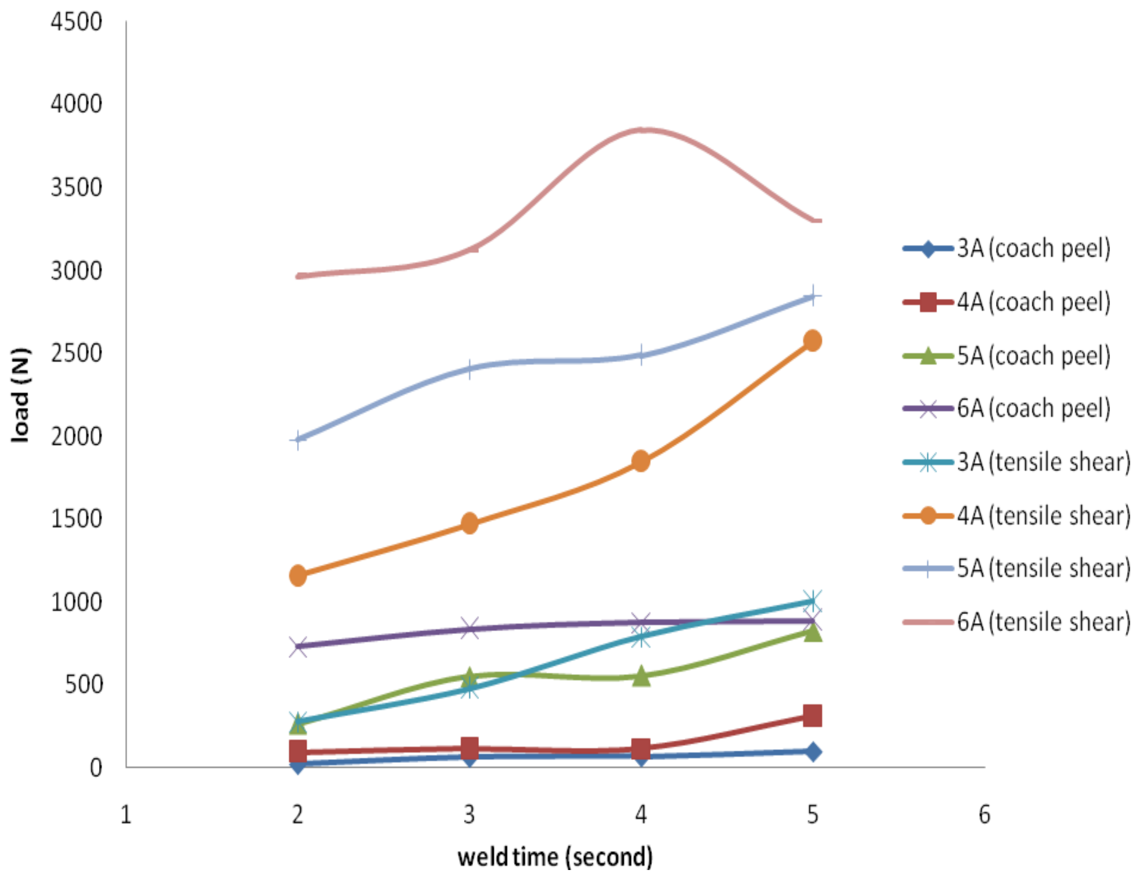


Figure 4.9 Combination graph between coach peel and tensile shear

From the result and discussion above, the chosen about the best joining type using spot welding process at same parameter setup can conclude. From observation to the test result data and picture of the specimen, the best type of specimen joining is tensile shear type. From the comparison the maximum load value in every test using tensile test machine shown the tensile shear load is higher than coach peel type load.

From the graph above (figure 4.7) shown the result of comparison between different orientation for mils steel material. Comparison between 3 ampere current supply for coach peel and tensile shear showed the differential of values. From starting value, the graph is almost near, but when the weld current increases the different values is also increase. The all result for coach peel type is nearest between each other but for tensile shear, the values are bigger than coach peel. The highest values for coach peel are not exceeding the highest value at 3 ampere (A) weld current for tensile shear.

The maximum load for tensile shear type is higher than maximum load at coach peel type because the effect of shear force. When the tensile shear type is doing the tensile test testing, when the force is applied to give a tensile strength the shear stress is occur at the surface of the weld specimen between the work pieces. Because of that the value of maximum load is increase according to the shear force and strength of the weld nugget itself. Mine while for the coach peel type, the strength only depends to the strength of the nugget at the joining part because it not produces a shear force.

The parameter setup is most important to ensure the safety of user, because many of vehicle using this joining type to joint part of material for their product. From this experimental, the optimum parameter setup for tensile shear type is finding, but for coach peel type the optimum parameter setup to weld 0.8 mm thickness of mild steel is not found. The result in graph of coach peel type above only shown the high maximum load but not shown the optimum parameter for this joining. Because of that the optimum parameter must be finding for every weld current and weld time to give a high strength of joining.

Chapter 5

Conclusion

5.1 Conclusion

The main objective of this study is to determine the strength of the joining process by using tensile test for spot weld joint. From the experimental result in this report the conclusion that can be made based on the main objective is, the result for this experimental is totally depend on the value of the parameters setup. The chosen of the right combination value of spot weld parameter setup will produce the strong joining.

Based on study, the parameters that can be programmed in the resistance welding machine are current, time and welding force [4]. Small change in setup this parameter can affect the result of strength of joining. So the selection of parameters for this study is relevant.

5.1.1 Welding Current and Time

The heat that produces during the welding process is proportional to time and square of current (Figure 5.1). The current and time are important for generates the heat but the heat that generate during the welding process is determined only by current. The time setup is only for control how long the current can pass through to the work piece. The heat that lost to the work pieces and to copper electrodes will increase according to increasing weld time (Pires et.al. 2005).

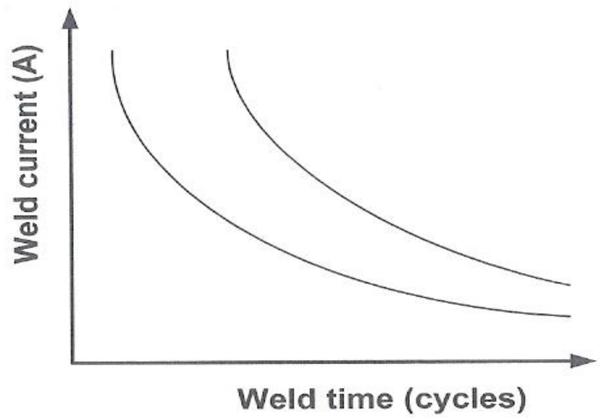


FIGURE 5.1 Current – time relationship

The size of the weld nuggets is increasing due to current and weld time increasing. In spot welding, if weld current is increased the welding time should be decreased because if the weld time also increases, the heat can damage the structure of the specimen and change their properties and also damage the electrode. Figure 5.2 show the simplest situation and are suitable to follow as rule for welding mild steel.

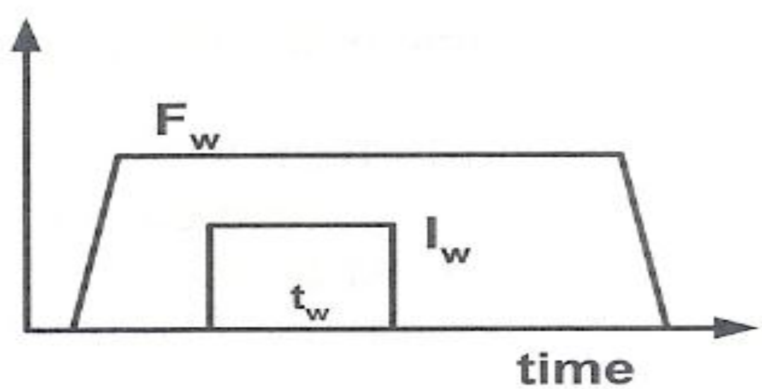


FIGURE 5.2 timing diagrams of current and force spot welding - *Iw*; welding time – tw ; rise time- tr – , welding force - Fw; forge force- F forges; anneling current

5.2 Recommendation

Studies of strength in spot weld using different parameter setup and different orientation can still be improve due for the next research: There are recommendations of this research:

I. Surface finishing

II. Heat treatment

III. Microstructures Properties by using of SEM machine.

All of these testing can be use to increase the strength of the joining and find the structure at the nugget and heat affected zone (HAZ) to compare the quality between type of joining using different parameter setup.

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