EXPERIMENTAL STUDY ON STRENGTH OF SPOT WELDED

HASBULLAH B ISHAK

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

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

NOVEMBER 2008

SUPERVISOR DECLARATION

We hereby declare that we have checked this project and in our opinion this project is satisfactory in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

Signature : ……………………………..
Supervisor : Mr. Muhamad B Mat Noor
Date : ……………………………..

Signature : ……………………………..
Name of Panel: ……………………………..
Position : LECTURER
Date : ……………………………..

STUDENT DECLARATION

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

Signature : ……………………….

Supervisor : Hasbullah B Ishak

Date : ……………………….

To my beloved father and mother

Mr. Ishak B Ibrahim
Mrs. Norizati Bt Zakaria

ACKNOWLEDGEMENT

In the praise of Almighty Allah, the Beneficent and Merciful-who showed the path of righteousness and blessed me to get the strength to embark upon this task of peeping into the realms of facts and events.

First of all, I would like to thank with heartfelt gratitude to my supervisor Mr. Muhamad B Mat Noor who has constantly spent his time helping me creation of present work and participated in the process of alteration. The encouragement and help I received from him has been simply beyond description.

I also feel obliged to general, lectures, staff of Faculty of Mechanical Engineering especially Dr. Md Mustafizur Rahman, Mr Hazami and Mr Rizal, for extending their full cooperation and commitment to help me done my research.

Finally, I express my thanks and immeasurable gratitude for every kind of support that I received from my family and friends especially Hashim B Ishak, Hasmiji B Ishak and Mohd Alfadully B Mohamad Saleh during my work which otherwise might not have been possible to undertaken by me.

ABSTRACT

In this paper, the objective is to investigate the strength of spot welding using variable thickness of sheet metal, weld time and weld current. Spot welded of the same material and different thickness combinations by overlapping joint were welded together to form a single spot. Thus, mild steel sheet of thickness 1.2mm and 1.5mm were studied and combined to form spot welded. Different parameters of welding such as welding current and welding time were used to weld the sheet metal for each thickness. Then tensile test machine was used to test the formability of spot welded and follow up by image analyzer testing to capture the image of spot welded nugget. The tensile test show that, the optimum parameter are at condition (T = 1.2mm, t = 3sec & I =5A) which produced 5.958kN of loading. The experimental findings show that resistance spot welding of different types of parameters and also different thickness of sheet metal shows different strength.

Keywords: Spot welding, different thickness, different weld current, different weld time, joint strength

ABSTRAK

Objektif dalam tesis ini adalah untuk mengkaji kekuatan bintik kimpal dengan berlainan ketebalan kepingan logam, masa kimpalan dan arus kimpalan. Proses bintik kimpalan yang sama bahan dan berlainan ketebalan dicantum dengan bertindih untuk membentuk satu bintik kimpalan. Oleh itu, kepingan logam ‘Mild Steel’ dengan ketebalan 1.2mm dan 1.5mm dikaji dan disambung bersama untuk membentuk proses yang dipanggil bintik kimpalan. Berlainan parameter seperti arus kimpalan dan masa kimpalan digunakan untuk mengimpal kepingan logam setiap ketebalan. Kemudian, mesin ujian kebolehtarikan digunakan untuk menguji pembentukan bintik kimpalan dan diikuti dengan ujian analisis imej untuk menangkap imej bintik kimpalan. Ujian kebolehtarikan menunjukknan, yang terbaik parameter adalah pada keadaan (T = 1.2mm, t = 3sec & I =5A) yang mana boleh menampung beban sebanyak 5.958kN. Penemuan ujikaji menunjukkan bahawa bintik kimpalan yang menggunakan berlainan parameter dan berlainan ketebalan kepingan logam mempunyai berlainan kekuatan.

Keywords: Bintik Kimpalan, berlainan ketebalan, berlainan arus kimpalan, berlainan masa kimpalan, kekuatan hubungan

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LIST OF SYMBOLS

E	Young's modulus
H	Heat
I	Current
K	Heat Losses
L	Length
m	Rate sensitivity
n	Strain hardening
Q	Heat generated
R	Resistance of the work
Rm	Ultimate tensile strength
r0, r45, r90	Anisotropy coefficients
Rp0.2	Yield strength
t	Duration of current
T	Thickness of sheet metal
v	Poisson's ratio
w	Width

LIST OF ABBREVIATIONS

C	Clamp
FLV	Forming limit curve
HAZ	Heat affected zone
RWMA	Resistance Welders Manufacturing Association

UNIVERSITI MALAYSIA PAHANG

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JUDUL: EXPERIMENTAL STUDY ON STRENGTH OF SPOT WELDED

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(TANDATANGAN PENULIS) (TANDATANGAN PENYELIA)

Alamat Tetap: 118 Felda Kemahang 1,
17500 Tanah Merah,
Kelantan

Mr. Muhamad B. Mat Noor
(Nama Penyelia)

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CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Resistance spot welding is an important process in industry. In electric resistance spot welding, the overlapping work is positioned between the water-cooled electrodes, and then the heat is obtained by passing a large electrical current for a short period of time. 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. Each spot welding is not performed on the same condition because of the alignment of sheets and electrodes as well as the surface condition. Spot welders can also be completely automated, many of the industrial robot found on assembly lines are spot welders. A further place where spot welding is used is in the orthodontist's clinic, where small scale spot welding equipment is used when resizing metal "molar bands" used in orthodontics.

The weld is made by a combination of heat, pressure and time. As the name resistance welding implies it is the resistance of the material to be welded to current flow that causes a localized heating in the part. The pressure exerted by the tongs and electrode tips, through which the current flows, holds the parts to be welded in intimate contact before, during and after the welding current time cycle. Spot welding can used to weld various sheet metals. Range of the sheets are in the (0.5 – 3.0) mm. It process are uses two shaped copper alloy electrodes to concentrate welding current and force between the materials to be welded. Then it is quickly heated to the melting point, and after the current is removed a nugget of welded metal is produced. The result is a small spot. The amount of heat released in the spot is determined by the amplitude and duration of the current. The current and duration are chosen to match the material, the sheet thickness and type of electrodes. Applying the current for too long can burn a hole right through the materials being welded. The behavior of resistance spot welding process is extremely important to the quality of the entire welding structure. 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. The resistance spot weld is unique because the actual weld nugget is formed internally with relation to the surface of the base metal. The gas tungsten-arc spot is made from one side only. The resistance spot weld is normally made with electrodes on each side of the workpiece. Resistance spot welds may be made with the workpiece in any position. Spot welding can be easily identified on many sheet metal goods, such as metal buckets. Aluminum alloys also can be spot welded. However, their much higher thermal conductivity and electrical conductivity mean that up to three times higher welding currents are needed. This requires larger, more powerful, and more expensive welding transformers. The strength of the spot welds in the vehicle structure determines the integrity of structural performance during vehicle operations. Most spot welds generally carry only shear forces, but the spot welds can experience a significant amount of the peel force, or force normal to the spot weld in certain loading conditions. The combination of stress states and geometric shapes of the spot welds lead to stress concentration that can result in fatigue crack initiation around the spot weld. The cracks degrade structural performance and increase noise and vibration of the vehicle structure. Therefore, understandings of the strength for the spot welds are very important in vehicle structure design. Some researchers had studied on the effects of geometric factors, such as nugget diameter, sheet thickness, specimen width, and base metal properties, on the fatigue behavior of the spot welds. Those studies showed that generally strength of spot welds depends on the loading conditions and geometric factors.

The 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. 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 strength of spot welded depends on these parameters. Small change of parameters will effect on strength.

1.2 PROBLEM STATEMENT

i. The increasing strength of spot welded depends on material used and spot welding parameters such as weld time and weld current.
ii. The heat generate must be suitable to the thickness of the specimen to prevent burn a hole right through the materials being welded.

1.3 OBJECTIVE

To investigate the strength of spot welding using variable thickness of sheet metal, weld time and weld current.

1.4 PROJECT SCOPE

This research is focus on strength of spot welding which is to investigate the best method to join the plate. This focus area is done based on the following aspect:

i. The material used in the project is mild steel with variable in thickness (1.2mm and 1.5mm) to produce spot welding with different strength.
ii. The equipment used in this project is spot welding machine with variable in current supply and time of welding.
iii. Tensile test machine used to determine the strength of the joining.
iv. Analyze the data

1.5 SUMMARY

This chapter is generally about project background, problem statement, objective of project and scope of the project in order to achieve the objectives as mentioned.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The main purpose of this literature review is to get information about the project from the reference books, journals, technical papers and websites. In this chapter I want to discuss all the in formations that I found from many sources.

2.2 DEFINITION OF SPOT WELDING

Resistance welding involves the generation of heat by passing current through the resistance caused by the contact between two or more metal surfaces. Small pools of molten metal are formed at the weld area as high current (1000–100,000 A) is passed through the metal. In general, resistance welding methods are efficient and cause little pollution, but their applications are somewhat limited and the equipment cost can be high.

Figure 2.1: Spot welding machine

Spot welding is a popular resistance welding method used to join overlapping metal sheets of up to 3 mm thick. Two electrodes are simultaneously used to clamp the metal sheets together and to pass current through the sheets. The advantages of the method include efficient energy use, limited workpiece deformation, high production rates, easy automation, and no required filler materials. Weld strength is significantly lower than with other welding methods, making the process suitable for only certain applications. It is used extensively in the automotive industry ordinary cars can have several thousand spot welds made by industrial robots. A specialized process, called shot welding, can be used to spot weld stainless steel.

Like spot welding, seam welding relies on two electrodes to apply pressure and current to join metal sheets. However, instead of pointed electrodes, wheel-shaped electrodes roll along and often feed the workpiece, making it possible to make long continuous welds. In the past, this process was used in the manufacture of beverage cans, but now its uses are more limited. Other resistance welding methods include flash welding, projection welding, and upset welding [Weman, 2003].

2.3 ADVANTAGES AND DISADVANTAGES OF SPOT WELDING

There are many advantages and disadvantages in spot welding. By comparing with the arc welding, spot welding is the best because it is new method and technology in welding.

2.3.1 Advantages

i. Efficient and cause little pollution.
ii. Efficient energy use
iii. Limited workpiece deformation
iv. High production rate
v. Easy automation
vi. No required filler materials

2.3.2 Disadvantages

i. Equipment cost is very high
ii. Difficult to set up optimum current and weld time

2.4 THE PRINCIPLE OF ELECTRICAL RESISTANCE SPOT WELDING

In the spot welding process, two or three overlapped or stacked stamped components are welded together as a result of the heat created by electrical resistance. This is provided by the work pieces as they are held together under pressure between two electrodes. Spot welding may be performed manually, robotically or by a dedicated spot welding machine. The similar spot welds having same property can be obtained in high production speeds by controlling welding current, electrode force and weld time automatically. The required low voltage (5–20 V) and high current intensity (2000–15,000 A) for welding process is obtained from transformators and the pressure is obtained from hydraulic, mechanic and pneumatic devices.[S. Aslanlar, A. Ogur, U. Ozsarac, E. Ilhan and Z. Demir, 2007]

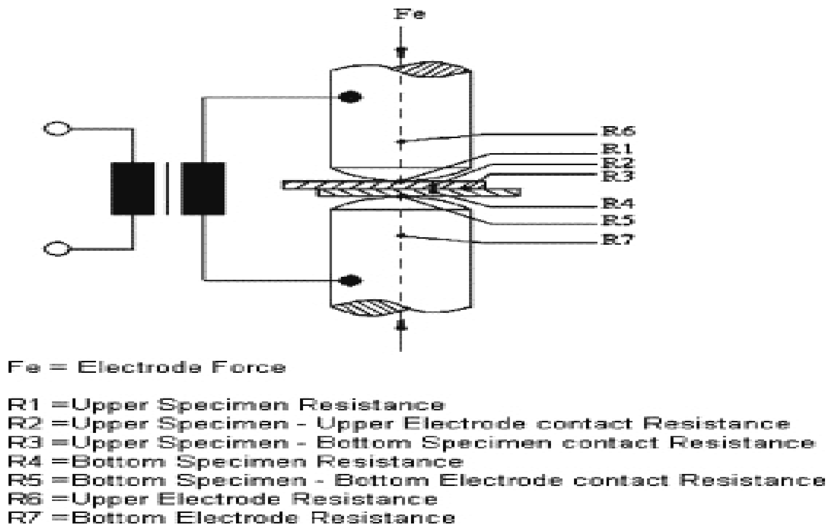


Figure 2.2: The resistances in electrical resistance spot welding [H.A. Nied, 1984].

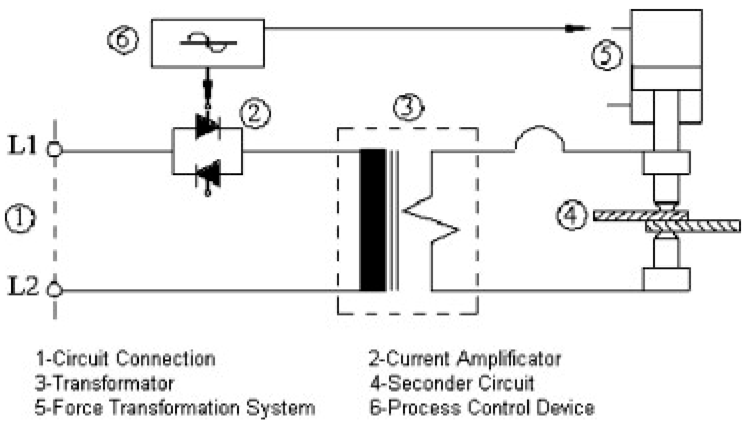


Figure 2.3: Electrical resistance spot welding machine [H.A. Nied, 1984].

The welding current must pass from the electrodes through the work. Its continuity is assured by forces applied to the electrodes. The sequence of operation must first develop sufficient heat to raise a confined volume of metal to the molten state. This metal is then allowed to cool while under pressure until it has adequate strength to hold the parts together. The current density and pressure must be such that a nugget is formed, but not so high that molten metal is expelled from the weld zone. The duration of weld current must be sufficiently short to prevent excessive heating of the electrode faces.

The heat required for these resistance welding processes is produced by the resistance of the workpieces 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 the amperage, the resistance of the conductor and the duration of current. These three factors affect the heat generated as expressed in the formula.

2.4.1 Heat Genaration

$$Q=I^2Rt \qquad (2.1)$$

Where

Q = heat generated, joules

I = current, amperes

R = resistance of the work, ohms

t = duration of current, seconds

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 Fig. 3.

2.4.2 Resistance

$$R=R_1+R_2+R_3+R_4+R_5 \qquad (2.2)$$

Here, the required resistance for spot weld formation is R_3. The higher the value of it means the higher the weldability. The magnitude of this resistance depends upon the surface condition of the base metal and the electrode, the size and contour of the electrode face and electrode force. This is a point of high heat generation, but the surface of the base metal does not reach the fusion temperature during the current passage, due to the high thermal conductivity of the other electrodes the fact that they are usually water-cooled.

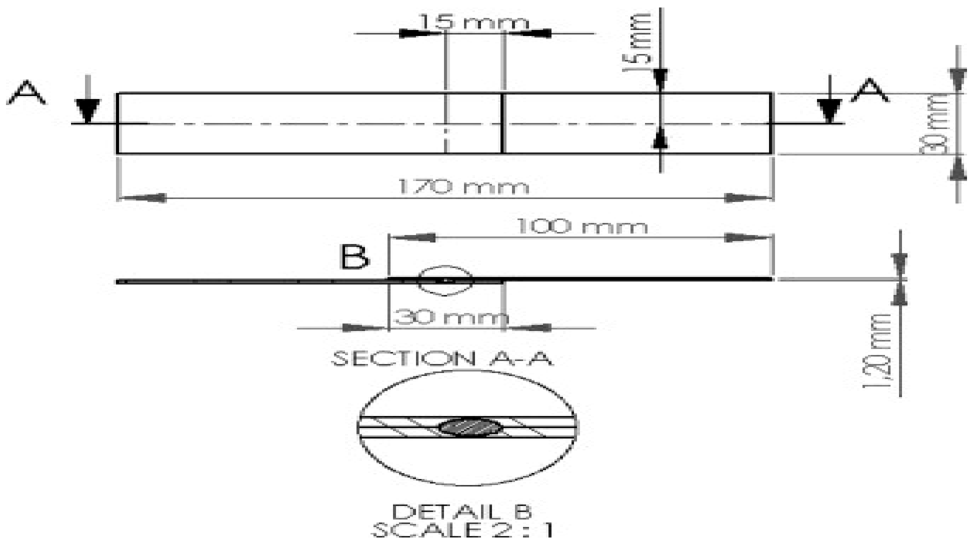


Figure 2.4: Dimension of tensile-shear test specimens

The resistance R in the heat formula is influenced by welding pressure through its effect on contact resistance at the interface between the workpieces. Pieces to be spot welded must be clamped tightly together at the weld location to enable the passage of the current. Everything else being equal, as the electrode force or welding pressure is increased, the amperage will also increase up to some limiting value.

Spot welds are discrete weld locations that look like small circles on the assembled components. They are not continuous, linear welds. Low volume components are usually done manually, whereas high volumes can be achieved best by using robots or dedicated weld equipment. Electrodes play a vital role in these devices. They must have adequate strength and hardness, because weld quality will deteriorate as tip deformation proceeds. In addition, a momentary reduction in electrode force permits the internal metal pressure to rupture unfused metal in weld zone. Internal voids or excessive electrode indentation may result. The welding process is generally performed in less than one second. This time is called as period.

2.4.3 Effect of Welding Time on Heat Formation

Squeeze time is the time interval between the initial application of the electrode force on the work and the first application of current. It is necessary to delay the weld current until the electrode force has attained the desired level. After that, the weld time is measured and adjusted in cycles of line voltage as are all timing functions. When it is held long the amount of molten metal increases and fused metal spurts out and a series of peaks and valleys occur on a microscopic scale on the surfaces of metal components and crystal structure of material changes. In addition heat affected zone (HAZ) extends. When the electrodes removed immediately, the heat dissipates and contact surface becomes dark. After the welding operation, the electrodes should be applied to the sheet to chill the weld. Hold time is necessary to allow the weld nugget to solidify before releasing the welded parts, but it must not be too long as this may cause the heat in the weld spot to spread to the electrode and heat it. When welding of galvanized carbon steel a longer hold time is recommended. However, it was advised that short time pulses are required in resistance welding of sheets thicker than 3 mm [H.A. Nied, 1984].

2.5 SPOT WELDING PARAMETERS

The 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. The parameters are:

1. Electrode force
2. Diameter of the electrode contact surface
3. Squeeze time

4. Weld time
5. Hold time
6. Weld current

2.5.1 Electrode Force

The purpose of the electrode force is to squeeze the metal sheets to be joined together. This requires a large electrode force because else the weld quality will not be good enough. However, the force must not be too large as it might cause other problems. When the electrode force is increased the heat energy will decrease. This means that the higher electrode force requires a higher weld current. When weld current becomes to high spatter will occur between electrodes and sheets. This will cause the electrodes to get stuck to the sheet.

One problem, though, is that the size of the contact surface will increase during welding. To keep the same conditions during the whole welding process, the electrode force needs to be gradually increased. As it is rather difficult to change the electrode force in the same rate as the electrodes are "mushroomed", usually an average value is chosen.

2.5.2 Diameter of the Electrode Contact Surface

One general criterion of resistance spot-welding is that the weld shall have a nugget diameter of $5*t^{1/2}$, “t” being the thickness of the steel sheet. Thus, a spot weld made in two sheets, each 1 mm in thickness, would generate a nugget 5 mm in diameter according to the $5*t^{½}$-rule. Diameter of the electrode contact surface should be slightly larger than the nugget diameter. For example, spot welding two sheets of 1 mm thickness would require an electrode with a contact diameter of 6 mm. In practice, an electrode with a contact diameter of 6 mm is standard for sheet thickness of 0.5 to 1.25 mm. This contact diameter of 6 mm conforms to the ISO standard for new electrodes.

2.5.3 Squeeze Time

Squeeze Time is the time interval between the initial application of the electrode force on the work and the first application of current. Squeeze time is necessary to delay the weld current until the electrode force has attained the desired level.

2.5.4 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. One cycle is 1/50 of a second in a 50 Hz power system. (When the weld time is taken from American literature, the number of cycles has to be reduced due to the higher frequency (60Hz) that is used in the USA.)

As the weld time is, more or less, related to what is required for the weld spot, it is difficult to give an exact value of the optimum weld time. For instance:

- 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.)

When welding sheets with a thickness greater than 2 mm it might be appropriate to divide the weld time into a number of impulses to avoid the heat energy to increase. This method will give good-looking spot welds but the strength of the weld might be poor [Dursun Ozyurek, 2007].

By multiplying the thickness of the sheet by ten, a good target value for the weld time can be reached. When welding two sheets with the thickness 1 mm each, an appropriate weld time is 10 periods (50Hz).

2.5.5 Hold Time

Hold time is the time, after the welding, when the electrodes are still applied to the sheet to chill the weld. Considered from a welding technical point of view, the hold time is the most interesting welding parameter. 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 electrode will then get more exposed to wear. Further, if the hold time is to long and the carbon content of the material is high (more than 0.1%), there is a risk the weld will become brittle. When welding galvanized carbon steel a longer hold time is recommended.

2.5.6 Weld Time

The weld current is the current in the welding circuit during the making of a weld. The amount of weld current is controlled by two things; first, the setting of the transformer tap switch determines the maximum amount of weld current available; second the percent of current control determines the percent of the available current to be used for making the weld. Low percent current settings are not normally recommended as this may impair the quality of the weld. Adjust the tap switch so that proper welding current can be obtained with the percent current set between seventy and ninety percent.

The weld current should be kept as low as possible. When determining the current to be used, the current is gradually increased until weld spatter occurs between the metal sheets. This indicates that the correct weld current has been reached.

2.6 MATERIAL

Steel has a higher electrical resistivity and lower thermal conductivity than the copper electrodes, making welding relatively easy. Low carbon steel is most suitable for spot welding. Higher carbon content or alloy steel tends to form hard welds that are brittle and could crack. Aluminum has an electrical resistivity and thermal conductivity that is closer to that of copper. However, aluminum's melting point is much lower than that of copper, making welding possible. Higher levels of current must be used for welding aluminum because of its low resistivity.

Galvanized steel (i.e. steel coated with zinc to prevent corrosion) requires a different welding approach than uncoated steel. The zinc coating must first be melted off before the steel is joined. Zinc has a low melting point, so a pulse of current before welding will accomplish this. During the weld, the zinc can combine with the steel and lower its resistivity. Therefore, higher levels of current are required to weld galvanized steel.

Carbon steel, also called plain carbon steel, is a metal alloy, a combination of two elements, iron and carbon, where other elements are present in quantities too small to affect the properties. The only other alloying elements allowed in plain-carbon steel are manganese (1.65% max), silicon (0.60% max), and copper (0.60% max). Steel with low carbon content has the same properties as iron, soft but easily formed. As carbon content rises the metal becomes harder and stronger but less ductile and more difficult to weld. Higher carbon content lowers steel's melting point and its temperature resistance in general.

Carbon content influences the yield strength of steel because they fit into the interstitial crystal lattice sites of the body-centered cubic arrangement of the iron molecules. The interstitial carbon reduces the mobility of dislocations, which in turn has a hardening effect on the iron. To get dislocations to move, a high enough stress level must be applied in order for the dislocations to "break away". This is because the interstitial carbon atoms cause some of the iron BCC lattice cells to distort.

2.6.1 Typical Composition of Carbon

- **Mild (low carbon) steel**: approximately 0.05–0.15% carbon content for low carbon steel and 0.16-0.29% carbon content for mild steel (e.g. AISI 1018 and AISI 1020 steel) [Smith, 2006]. Mild steel has a relatively low tensile strength, but it is cheap and malleable; surface hardness can be increased through carburizing [W.F, 2006].

- **Medium carbon steel**: approximately 0.30–0.59% carbon content (e.g. AISI 1040 steel) [Smith, 2006]. Balances ductility and strength and has good wear resistance; used for large parts, forging and automotive components [Hashemi, 2006].

- **High carbon steel**: approximately 0.6–0.99% carbon content [Smith, 2006]. Very strong, used for springs and high-strength wires [J, 2006].

- **Ultra-high carbon steel**: approximately 1.0–2.0% carbon content [Smith, 2006]. Steels that can be tempered to great hardness. Used for special purposes like (non-industrial-purpose) knives, axles or punches. Most steels with more than 1.2% carbon content are made using powder metallurgy and usually fall in the category of high alloy carbon steels.

Mild steel is the most common form of steel as its price is relatively low while it provides material properties that are acceptable for many applications. Mild steel has low carbon content (up to 0.3%) and is therefore neither extremely brittle nor ductile. It becomes malleable when heated, and so can be forged. It is also often used where large amounts of steel need to be formed, for example as structural steel. Density of this metal is 7,861.093 kg/m^3 (0.284 lb/in^3), the tensile strength is a maximum of 500 MPa (72,500 psi) and it has a Young's modulus of 210 GPa [Ameristeel article].

2.7 TENSILE TEST

The main focus in the study was the forming limit in the plane strain condition but other strain states were also considered. The main expected advantages of this test procedure as compared to the conventional forming limit determination would be a fast and simple test with no need of other testing equipment than a uniaxial tensile testing machine, a low scatter in experimental results, and no influence of friction on the results. Another advantage is that this test procedure simplifies the usage of optical equipment for the strain determination.

Table 2.1: Material characteristics for the two materials

Material	t (mm)	$R_{p0.2}$ (MPa)	R_m (MPa)	r_0	r_{45}	r_{90}	n	E (GPa)	ν
Mild steel	1.0	137	284	1.99	2.61	2.13	0.24	210	0.3
High strength steel	1.0	278	469	0.98	0.66	1.22	0.21	210	0.3

The basic mechanical properties of these materials are given in table. In the table, *t* is the initial sheet thickness, *R*p0.2 the yield strength, *R*m the ultimate tensile strength, *r*0, *r*45, *r*90 the anisotropy coefficients, *n* the strain hardening exponent, *E* the Young’s modulus and *v* the Poisson’s ratio. Stress–strain relations describing the work-hardening behaviour of the materials. These data were determined through standard uniaxial tensile tests. The curves are determined through the conventional method by stamping specimens of different widths to fracture and determine the strain levels by circle grid evaluation. The curves are fourth order polynomial fits of the measured strain data points. As can be seen, the material properties differ significantly between the grades. The high strength steel grade has yield stresses and tensile strengths of about two to three times as high as the mild steel. The anisotropy coefficients differ significantly. The high strength steel generally, show lower formability. The forming limit in plane strain is about 40% for the mild steel and about 30% for the high strength steel.

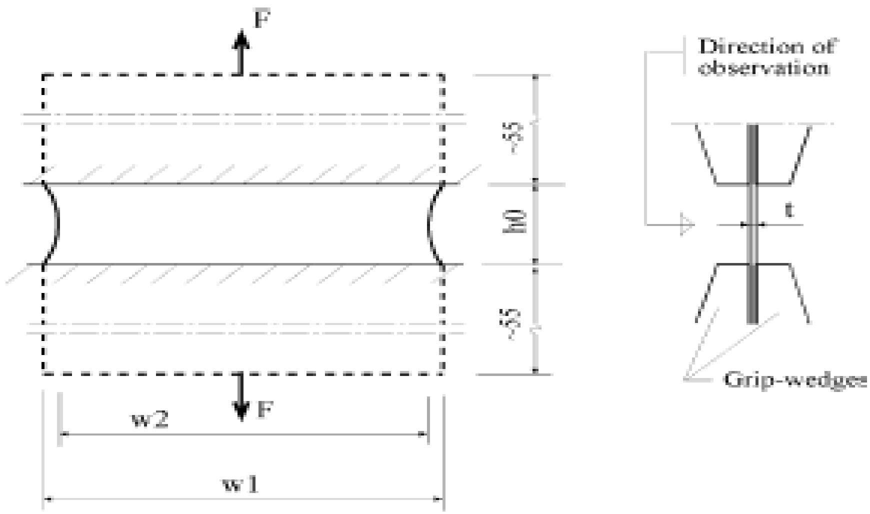


Figure 2.5: Drawing of specimen geometry

The experimental tensile tests are applied to obtain strength of selected specimens. General test configuration of tensile-shear spot-welded joints is illustrated in figure. Forces are applied at the two end of the specimen until the joining is fracture.

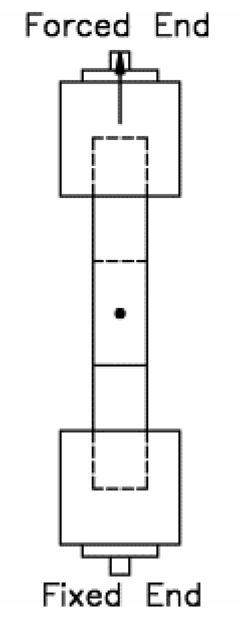


Figure 2.6: General test configuration for hot spot-welded joints specimens

The experiments were performed in an uniaxial material testing machine. The testing machine is built up with a load frame of a solid T-slot table, columns and a hydraulically maneuverable crosshead to which the servo-hydraulic actuator with capacity of ±100 kN is mounted. Control and data acquisition is performed by computer boards and specially designed programs. To be able to clamp the specimen in the desirable manner, special attention was put on the shaping of the wedges, specially their surface towards the specimen. Sliding between the specimen and the wedges should be avoided during loading (or kept to a minimum).Measuring equipment, consisting of two cameras and a computer for picture grabbing and analysis [K. Galanius, 2001], was used in order to measure deformations and strain distributions in the specimens during testing. Specimens used for optical deformation measurements were sprayed with a dark colour forming a random pattern. The other specimens were equipped with circle grids in order to facilitate strain measurements after testing. The test was run in deformation control with the initial piston rate of 0.2 mm/min and was, after the elastic limit, successively increased to about 0.5 mm/min. After the crack was opened to at least half the specimen width and the applied load was decreased to about one third of the maximum, the test was stopped.

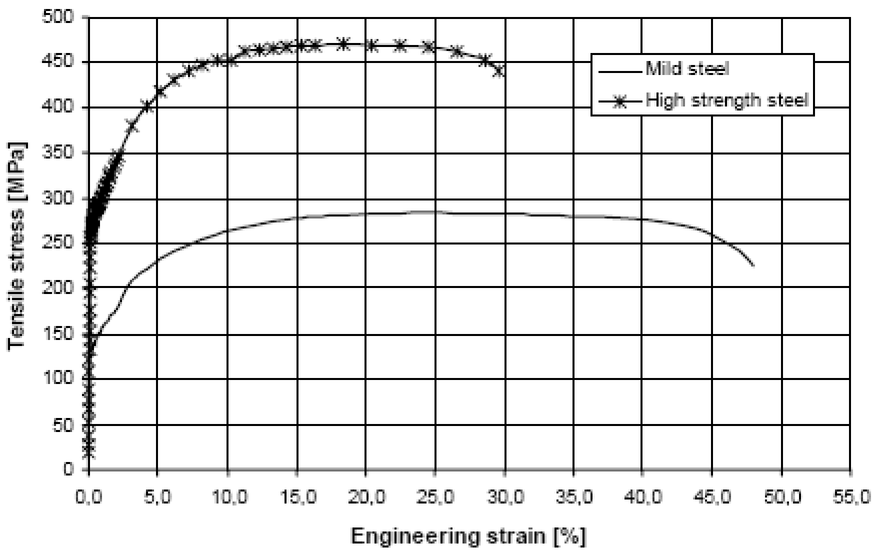


Figure 2.7: Tensile stress–strain curves for the materials

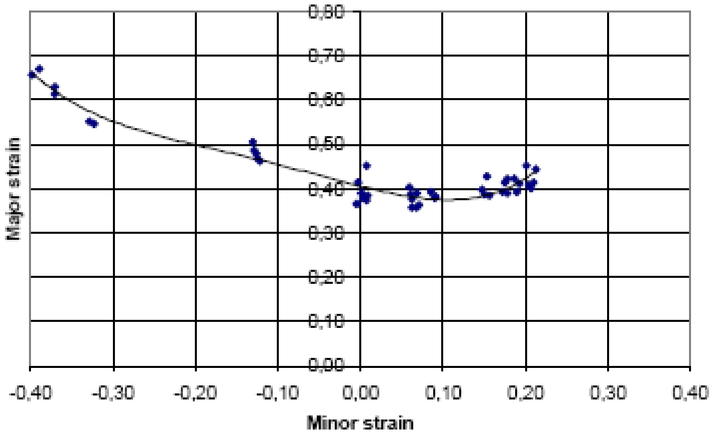


Figure 2.8: Forming Limit Curve (FLV) for Mild steel

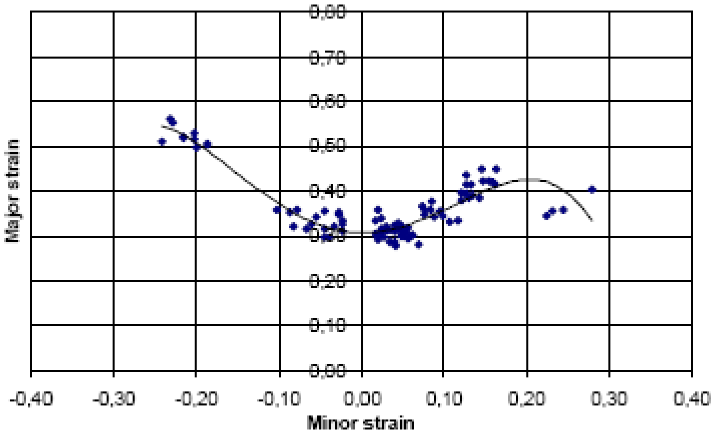


Figure 2.9: Forming Limit Curve (FLV) for High Strength Steel

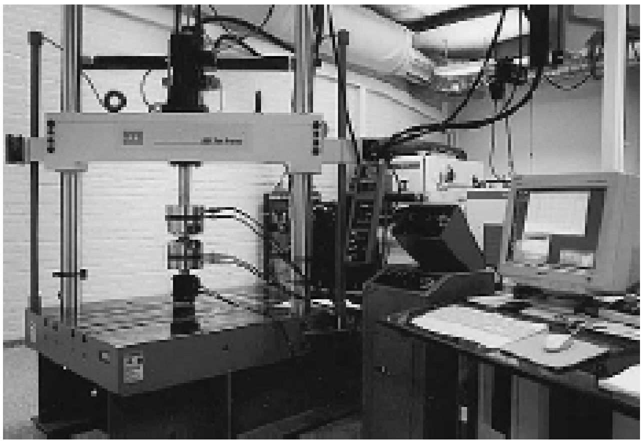


Figure 2.10: Testing equipment used for the experiment

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

To achieve the goals of this project, a structure of overall methodology has been planned and illustrated as guideline. There are six main methods, which are:

1. Literature Review
2. Dimension of specimen
3. Spot weld
4. Testing
5. Analyze
6. Documentation

Each of these methods is explained clearly under methodology of project below.

3.2 FLOW CHART

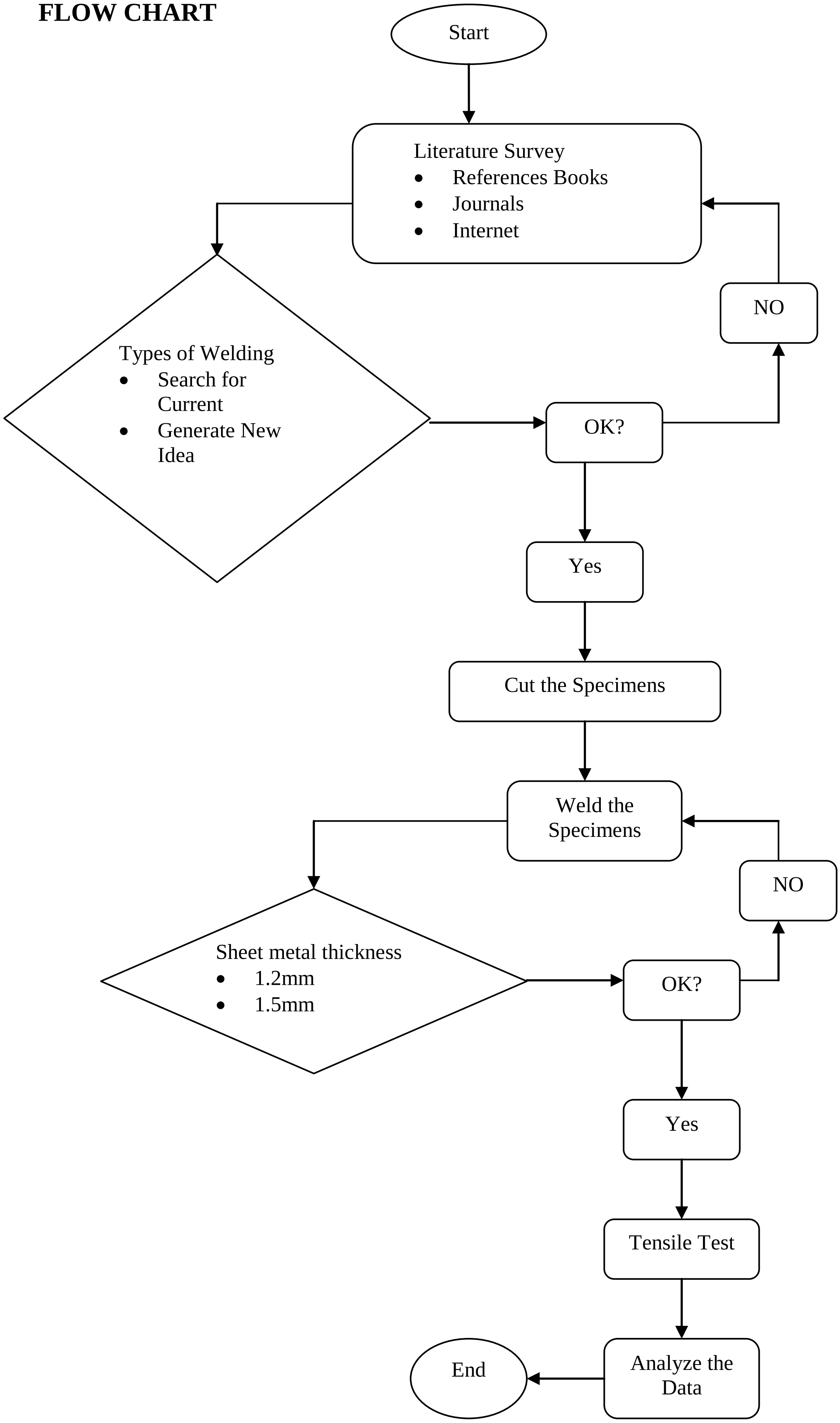


Figure 3.1: Flow chart of overall FYP

3.3 LITERATURE REVIEW

The main purpose of this literature review is to do preliminary studies and research about the project from the reference books, journals and websites. First of all, the title must be understood very well so it can be easy to find information about the title. Materials that found from journals, reference books and websites can help writer what is the project is about, what to search, where to search and help identify the purpose and objective of the project. In this chapter, I want to discuss all the in formations that I found from many sources.

3.4 DIMENSION OF SPECIMEN

There are the dimension of the specimen where used in the experiment. Those specimens are same in width and length but different in thickness which 1.2mm and 1.5mm.

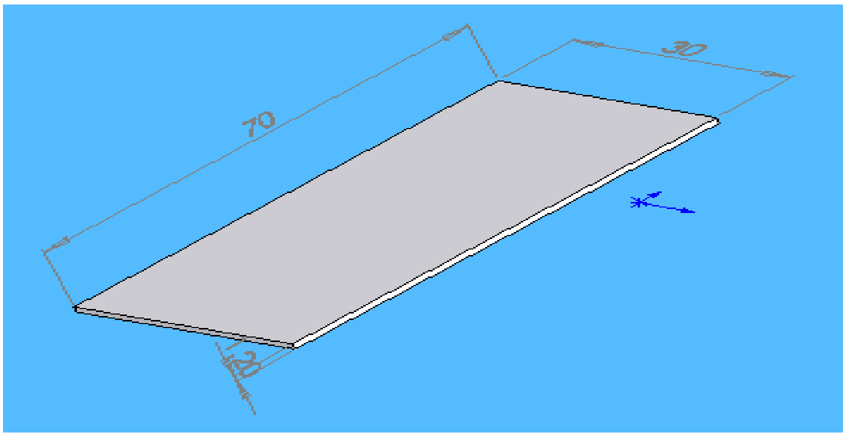


Figure 3.2: Dimension of 1.2mm in thickness of specimen

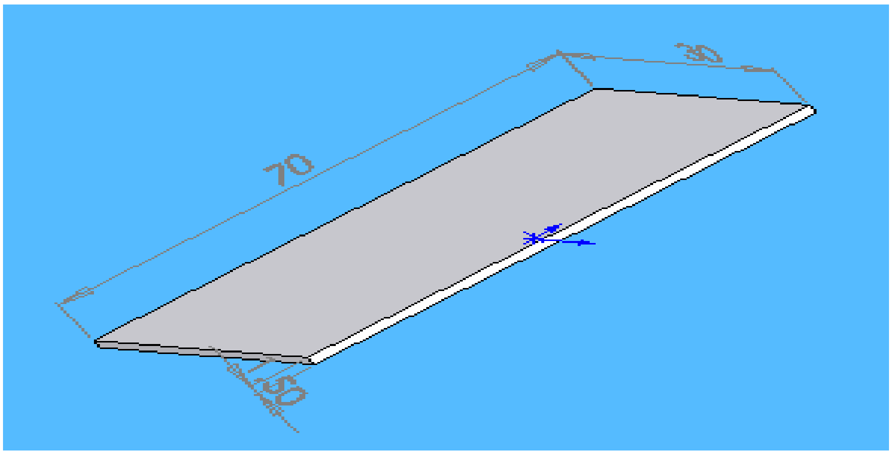


Figure 3.3: Dimension of 1.5mm in thickness of specimen

3.5 SPOT WELDING PROCESS

After the dimension is approved by the supervisor, the welding process is started. To do the welding process, there are several step must be followed:

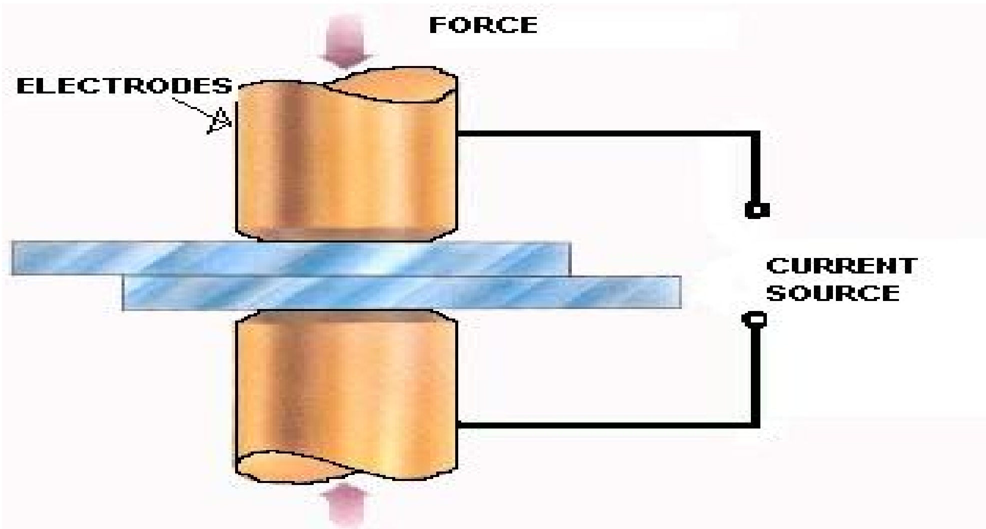


Figure 3.4: Welding process

Tong pressure settings should be made ONLY when power cord is disconnected from the primary power input supply

1. Close tongs and measure space between electrode tip contact surfaces.
2. Measure the thickness of the total weldment
3. Adjust tong gap to measurement of step 2 less half the thinnest weld number.
4. Insert the parts to be welded between the electrode tips and bring tips to welding pressure. There should be a slight deflection of the tongs. This may be measured with a straight edge set on the tong longitudinal axis.
5. Energize the spot welding machine and make a sample weld.
6. Test the weld by visual and mechanical means. Check the electrode tip for deformation and contamination.
7. Adjust tong pressure as required
8. Weld the sheets metal.
9. Observe the deformation and shape of the surface contact points at both sides of the weld. Excessive ‘dishing’ of the surface contact point indicates one or more following;
    - Excessive tong pressure.
    - Weld time too long
    - Misalignment of the electrode tips.
10. Repeat steps 1 till 8 if dishing is occurs.

During welding process, many problems occur because the weld current, weld time and electrode are not suitable with the thickness of the material. Below are troubles always occurring in spot welding process:

Table 3.1: Trouble in spot welding

TROUBLE	REMEDY
Tips overheating	• Not enough tong pressure. Increase tong pressure • Weld time too long. Reduce weld time • Material too thick for the spot welding machine
Tips arcing on material	• Not enough tong pressure. Increase tong pressure • Tips not aligned correctly. Realign tips or dress tips to proper diameter • Base material may be welded to tips causing high resistance and poor electrical current flow. Clean or dress tips
Spatter or molten material being expelled out during welding operation	• Incorrect tip alignment. Dress tips so that they align and are flat on the material • Excessive tong pressure. Reduce tong pressure • Output amperage too high. Reduce amperage setting, if applicable (not available on air-cooled models) • Weld time too long. Reduce weld time
Inconsistent weld nugget	• Inconsistent weld time. Install a weld timer, if applicable. • Not enough tong pressure. Increase tong pressure. • Hole in middle of weld. Contact area of tips is too large. Change to a smaller tip diameter or dress tips back to original diameter

Hole in middle of weld.	• Contact area of tips is too large. Change to a smaller tip diameter or dress tips back to original diameter
Poor weld or no weld at tips.	• Material too thick for spot welding machine. Check that material thickness is within capacity of spot welding machine • Tongs are too long. Reduce tong length. • Remove coating from material for intimate contact between pieces. Remove oxides and chemical compound including galvanized coating

These troubles will be effect to the strength of the spot weld. To avoid these problems, spot welding machine must be exactly setting before start welding process.

3.6 TENSILE TEST PROCESS

After finish spot welding process, Instron tensile test(3369) machine has been conducted to measure the strength of spot welded. Before run the machine, parameter of machine must be setting first such unit, dimension of specimen, gauge length, grip length and data collection then save. The specimen put between two jaws and run the machine. The value of strength of that specimen will be appearing on the screen.

Figure 3.5: Instron Tensile Test

CHAPTER 4

RESULT AND DISCUSSIONS

4.1 INTRODUCTION

In this chapter the result from the testing using tensile test machine will be assessed and also tensile properties of the specimen of spot welding will be study. The objectives of this experiment to investigate the strength of spot welding using variable thickness of sheet metal, weld time and weld current.

The result of tensile test from different type of welding will be shown in table below. For the evaluation of tensile strength of the specimen, the specimen with thickness of 1.2mm and 1.5mm are prepared and the tensile test is conducted, the resultant 'maximum load – weld current' relationship being shown in the figure.

4.2 RESULT

Seventy two specimens were spot welded according to the experimental design given in Table 4.1, Table 4.2 and Table 4.3. Three specimens were spot welded for each condition and all of the specimens being used for testing the tensile shear strength. The specimen of the spot welding were tested to study the strength of spot weld zone observe the tensile properties as shown by the Maximum Load vs Weld Current relationship in figure below. In this experiment, three parameters had been considered like thickness of sheet metal, weld time and weld current. Difference weld time, weld current and thickness of sheet will produced difference strength of spot welded.

For 2, 3 and 4 seconds weld time, the evaluation of the characteristics of the welded material will observe the tensile properties as shown in figure.

Table 4.1: Tensile properties for 2 seconds welding time

Current, A	Max Load,kN	
	1.5mm	1.2mm
2	0.321	1.477
3	1.744	2.882
4	3.315	4.471
5	5.524	5.804

Table 4.2: Tensile properties for 3 seconds welding time

Current, A	Max Load,kN	
	1.5mm	1.2mm
2	1.325	1.563
3	2.633	2.969
4	3.844	4.519
5	5.796	5.958

Table 4.3: Tensile properties for 4 seconds welding time

Current, A	Max Load,kN	
	1.5mm	1.2mm
2	1.368	1.765
3	3.187	3.407
4	3.949	4.407
5	5.885	5.665

4.3 DISCUSSION

For 2 seconds weld time, the evaluation of the characteristics of the welded material will observe the tensile properties as shown by the Maximum Load vs Weld Current relationship in Figure 4.1.

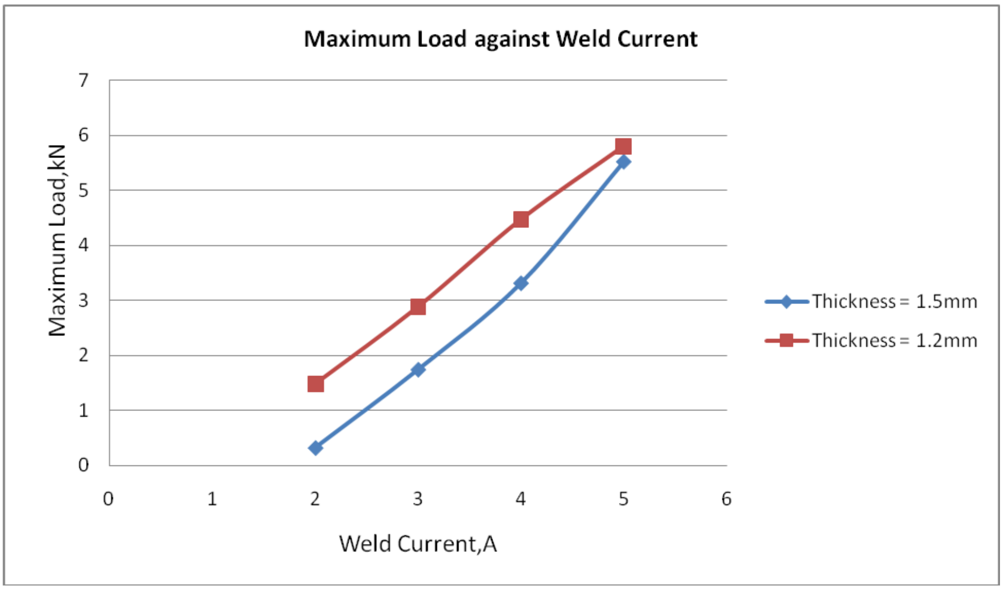


Figure 4.1: For weld time = 2s

For 3 seconds weld time, the evaluation of the characteristics of the welded material will observe the tensile properties as shown by the Maximum Load vs Weld Current relationship in Figure 4.2.

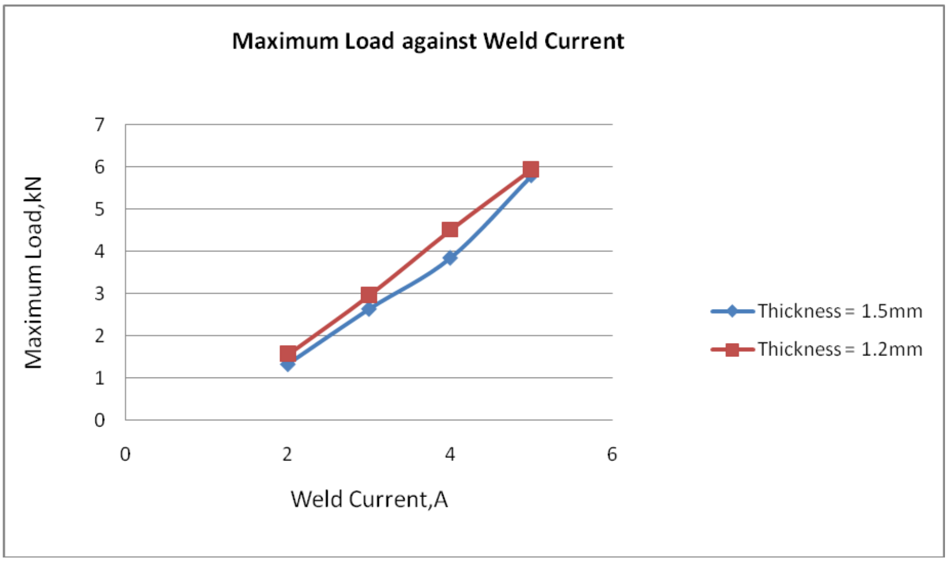


Figure 4.2: For weld time = 3s

For 4 seconds weld time, the evaluation of the characteristics of the welded material will observe the tensile properties as shown by the Maximum Load vs Weld Current relationship in Figure 4.3.

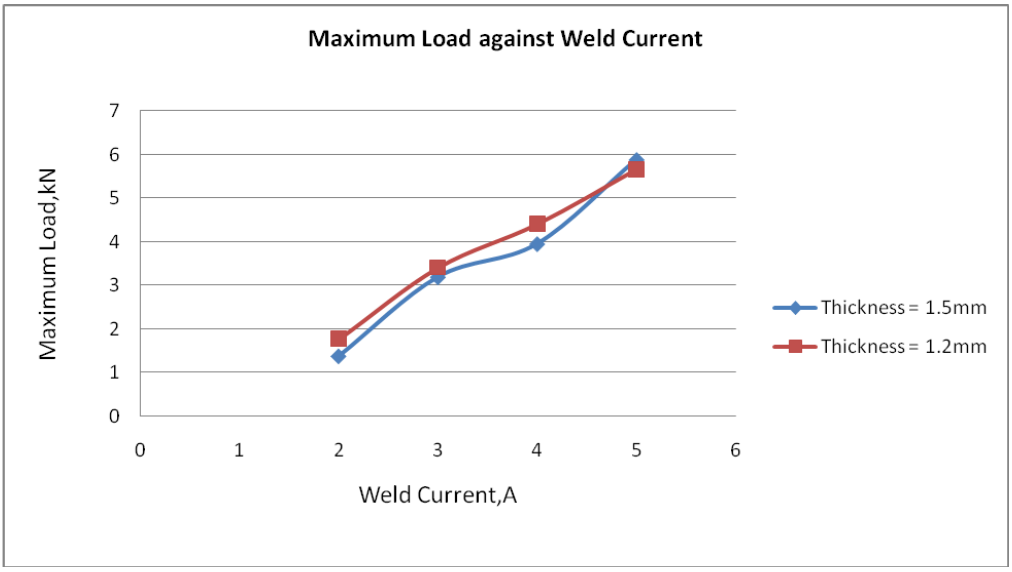


Figure 4.3: For weld time = 4s

Table 4.1 shows the average data of tensile properties during the tensile test. The specimen of spot welding was tested in tensile testing machine. From the table, we can see the average load of each weld current for each thickness at the constant weld time is shown. The highest average maximum load for 1.2mm thickness is 5.804kN and 5.524kN for 1.5mm thickness are located at the column 5A in welding current supply. The lowest average maximum load for 1.2mm thickness is 1.477kN and 0.321kN for 1.5mm thickness are located at the column 2A in welding current supply.

Table 4.2 shows the average data of tensile properties during the tensile test. From the table, we can see the average load of each weld current for each thickness at the constant weld time is shown. The highest average maximum load for 1.2mm thickness is 5.958kN and 5.796kN for 1.5mm thickness are located at the column 5A in welding current supply. The lowest average maximum load for 1.2mm thickness is 1.563kN and 1.325kN for 1.5mm thickness are located at the column 2A in welding current supply.

Table 4.3 shows the average data of tensile properties during the tensile test. From the table, we can see the average load of each weld current for each thickness at the constant weld time is shown. The highest average maximum load for 1.2mm thickness is 5.665kN and 5.785kN for 1.5mm thickness are located at the column 5A in welding current supply. The lowest average maximum load for 1.2mm thickness is 1.765kN and 1.368kN for 1.5mm thickness are located at the column 2A in welding current supply.

All the figure above shown, for weld time equal 2 seconds and 3 seconds, maximum load increasing when weld current increase. The curve shown, maximum load for 1.2mm thickness always higher than 1.5mm thickness specimen.

For weld time equal to 4 seconds, maximum load for the first three point increase when increasing weld current, but maximum load for the last point for 1.2mm thickness specimen decreasing because crack occur at the nugget. All the values of maximum load increase when increasing weld current except at the last point for 1.2mm thickness specimen.

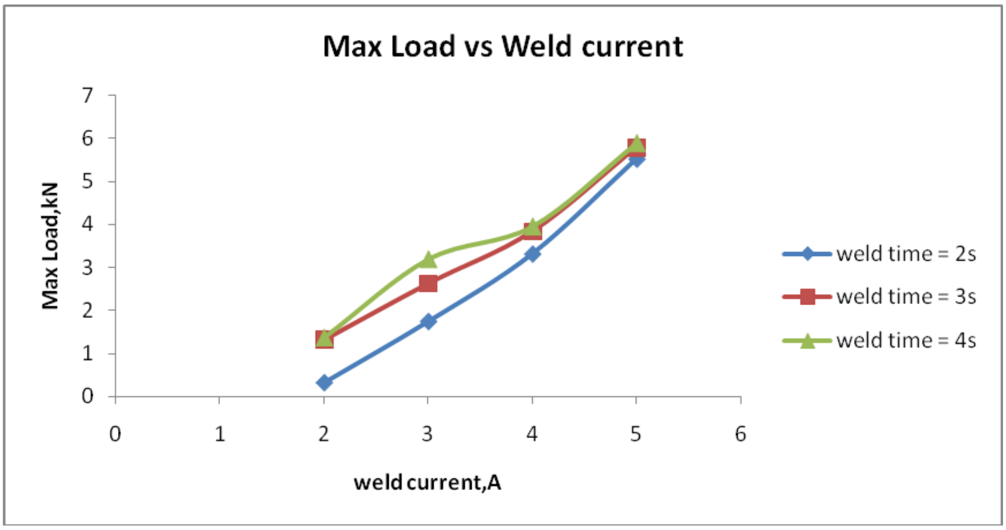


Figure 4.4 : For thickness 1.5mm

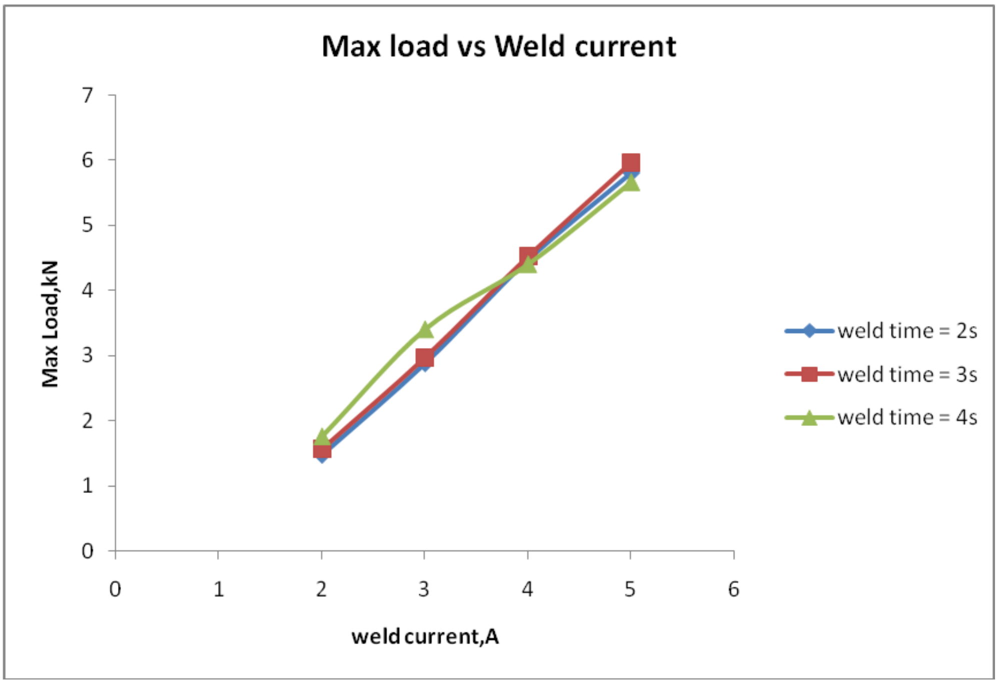


Figure 4.5 : For thickness 1.2mm

Figure 4.4 and 4.5 above shown two comparison graph for 1.2mm and 1.5mm thickness of maximum load vs weld current relationship. For weld time equal to 2 seconds and 3 seconds, the graph shown maximum load increase when increasing welding current.

For weld time equal to 4 seconds,the first two point shown, maximum load increase when increasing welding current. But the last two point shown, maximum load decrease when increasing welding current. At that point, the slope for 1.2mm thickness more descent than 1.5mm because obvious crack occur at that condition.

Optimum parameter for 1.2mm thickness is at (t = 3sec & I = 5A) where produce load about 5.958kN. Optimum parameter for 1.5mm thickness is at (t = 4sec & I = 5A) where produce load about 5.885kN. From the calculation 1.2% of 1.2mm thickness stronger than 1.5mm.

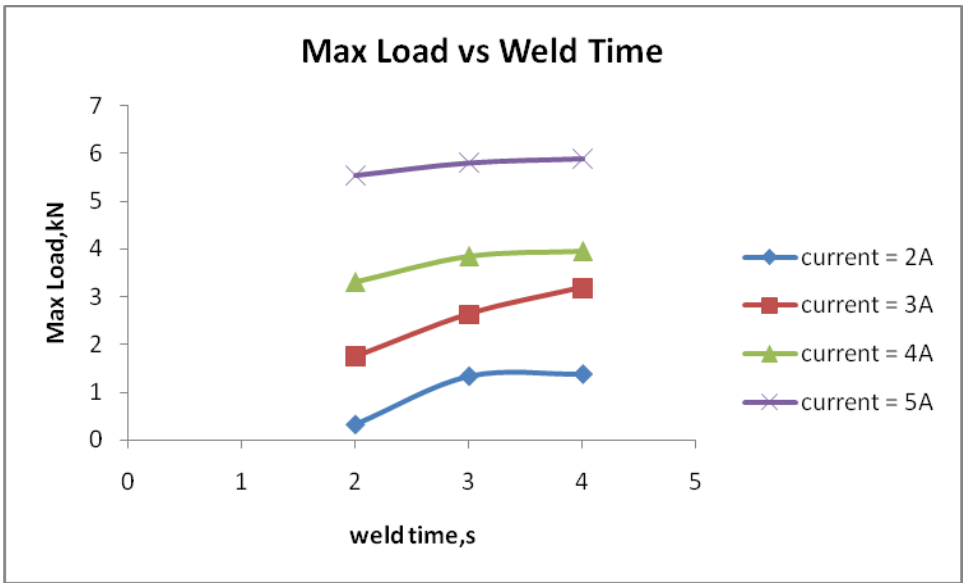


Figure 4.6: For thickness 1.5mm

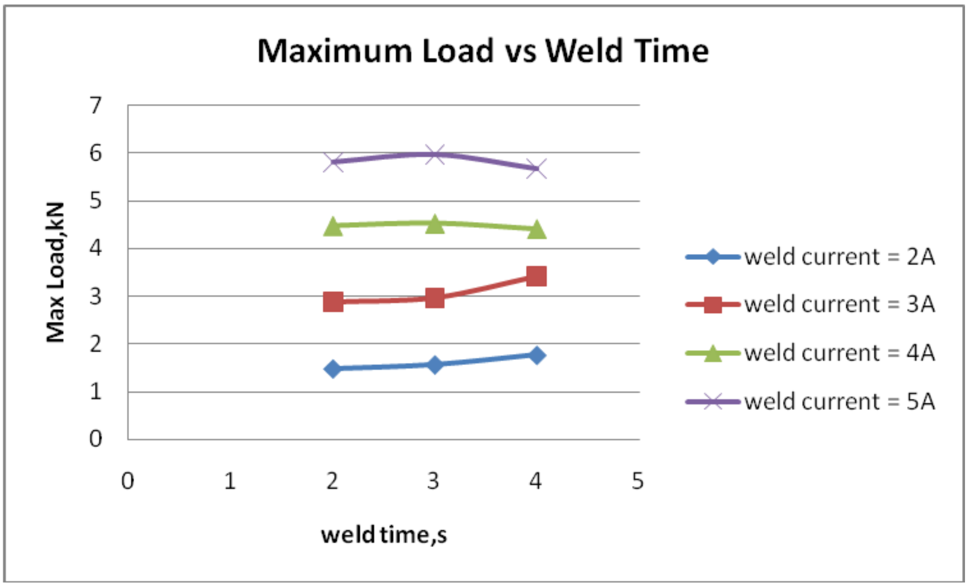


Figure 4.7: For thickness 1.2mm

Figure 4.6 and 4.7 above shown that, the relationship between maximum load and welding time for 1.5mm thickness and 1.2mm thickness. For 1.5mm thickness, maximum load for each point is proportionally increased when increasing welding time.

For 1.2mm thickness, at welding current equal to 2 Ampere and 3 Ampere, maximum load will be increase when welding time increasing. At welding current equal 4 Ampere and 5 Ampere, the first two points showed that, maximum loading increase with increasing welding time. But the last point showed that, maximum loading decrease when increasing welding time because excessive heat input produced during spot welding process.

From the calculation 2.5% decrement maximum loading occurred when apply 4 Ampere welding current and 5% when apply 5 Ampere welding time. These results shown that, more heat input excessive occur at 5 Ampere than 4A.

4.3.1 Crack

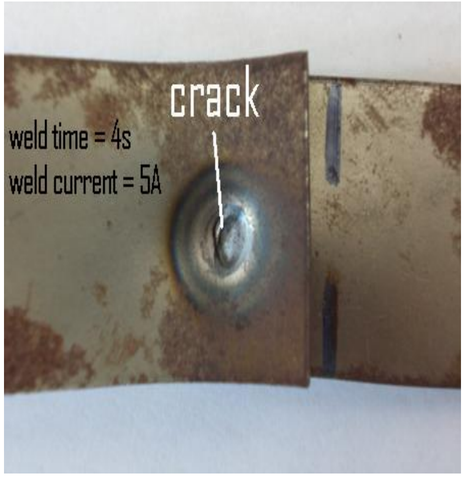


Figure 4.8: Before tensile test **Figure 4.9:** After tensile test

Figure 4.8 and 4.9 were shown that, the crack before and after tensile testing. It occur at condition (t = 4sec & I = 5A) and (t = 4sec & I = 4A) for 1.2mm thickness. These failures occur because excessive heat input at this condition. These problems will be preventing with increase the thickness at this welding condition.

4.3.2 Behaviour of Failure Specimen

Type of failure for all specimen for tensile shear are known as knotting. Knotting means, the attraction of nugget makes a hole like a round. Figure 4.10 and 4.11 are shown two different behavior of failure in thus experiment.

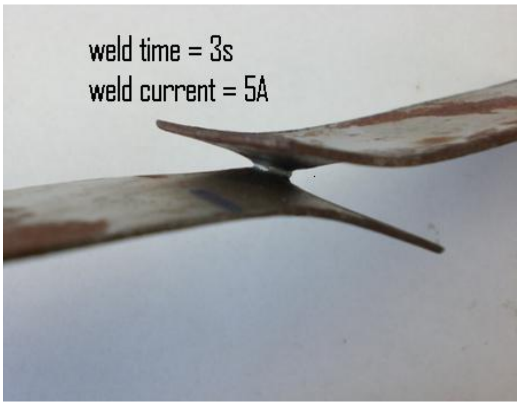


Figure 4.10: High joint strength

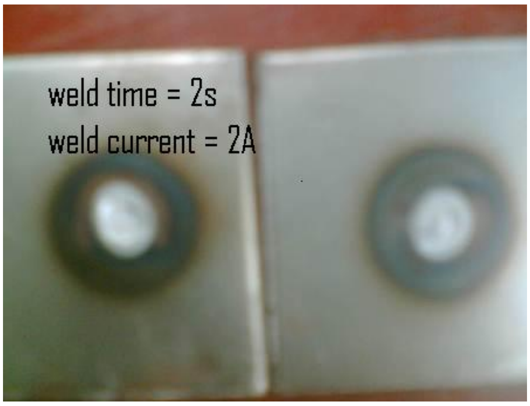


Figure 4.11: Low joint strength

The failure at condition (t = 3sec & I = 5A) as shown in figure 4.10 occur at optimum condition of spot welded. Maximum load at this condition is about 5.958kN. For low joint strength, failure occurs without knotting on nugget of spot welded. The joining strength quickly fails by separate without damage the specimen because not enough heat input applying. This behavior occur at (t = 2sec & I = 2A) condition and the maximum load is about 0.321kN as shown in figure 4.11.

4.3.3 Image Analyzer

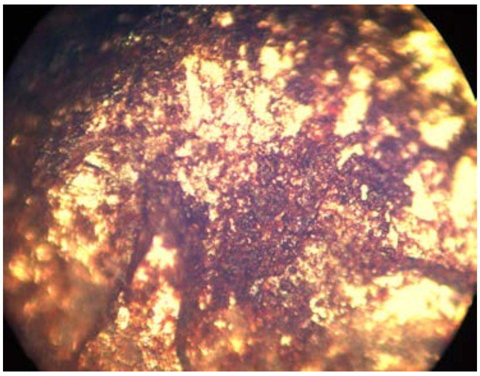


Figure 4.12: Max load = 5.804kN

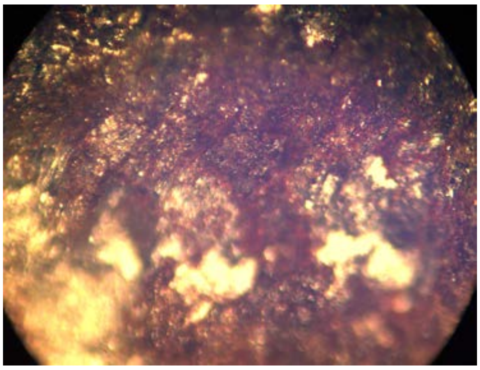


Figure 4.13: Max load 5.524kN

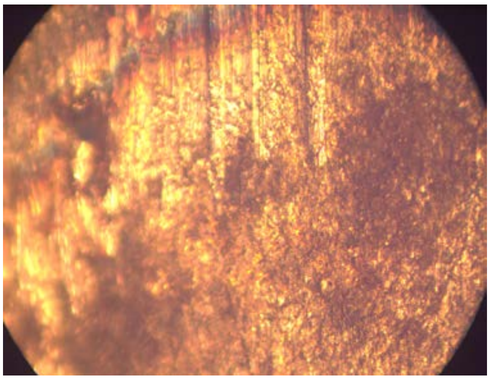


Figure 4.14: Max load = 1.477kN

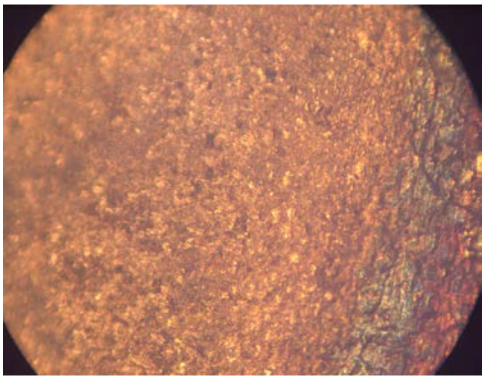


Figure 4.15: Max load = 0.321kN

Figure 4.12, 4.13, 4.14, 4.15 are shown the image of spot welded nugget capture by image analyzer. There are different image produced when changing the parameter. From the observation of the specimen while the specimen was tested, it observed that failure quickly occurred at the thick sheet metal compare to the thin sheet metal. This clearly shows that the sheet metal with 1.2mm in thickness more suitable in this welding condition.

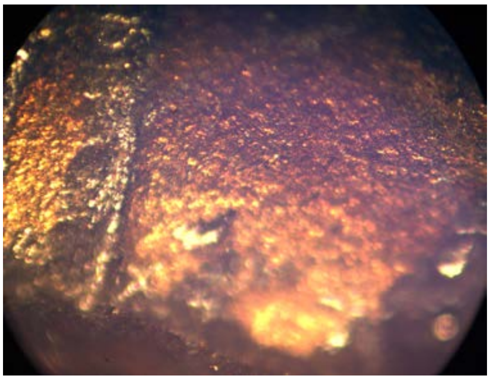


Figure 4.16: Max load = 5.958kN

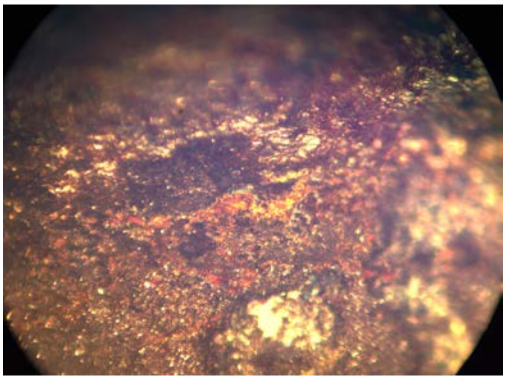


Figure 4.17: Max load = 5.796kN

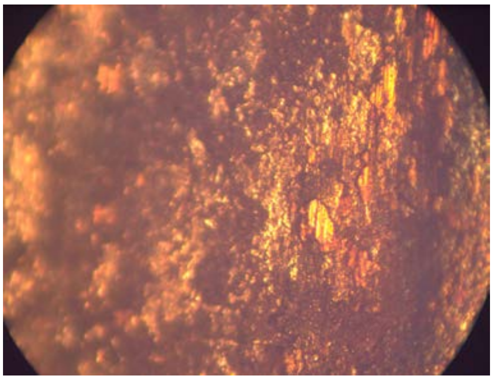


Figure 4.18: Max load = 1.563kN

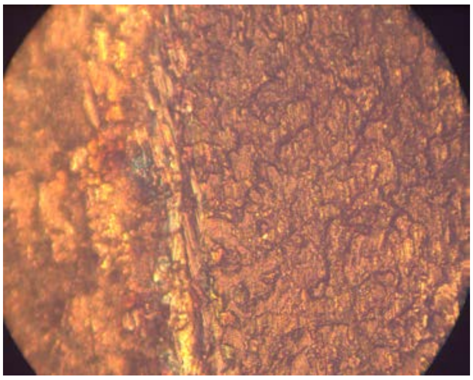


Figure 4.19: Max load = 1.325kN

Figure 4.16, 4.17, 4.18, 4.19 are shown the image of spot welded nugget capture by image analyzer. There are different image produced when changing the parameter. Once increasing the welding time, heat of the effected zone increasing too. So, the strength of spot welded nugget also increase as shown in figure 4.16. The result shown, the highest and lowest values of the Maximum Load are at the same welding condition like before but the values are difference. The value of Maximum Load increase when increasing the weld time. From the observation of the specimen while the specimen was tested, it observed that failure also quickly occurred at the thick sheet metal compare to the thin sheet metal. This clearly shows that the sheet metal with 1.2mm in thickness more suitable in this welding condition.

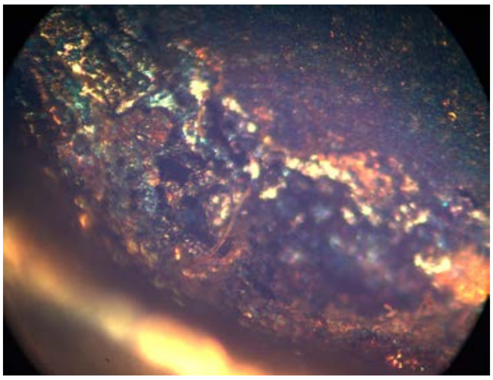


Figure 4.20: Max load = 5.665kN

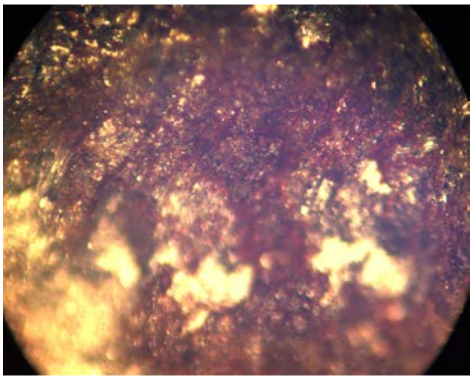


Figure 4.21: Max load = 5.785kN

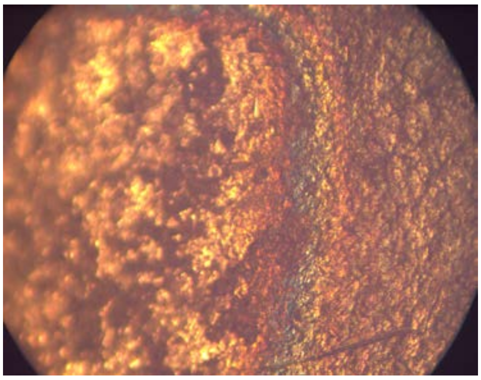


Figure 4.22: Max load = 1.765kN

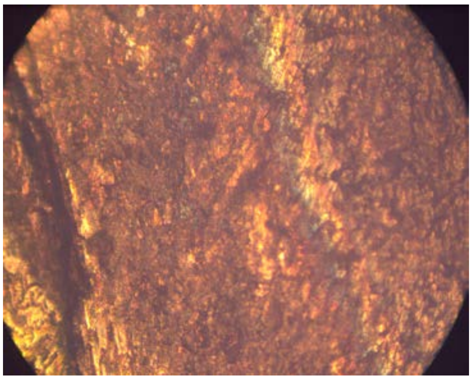


Figure 4.23: Max load = 1.368kN

Figure 4.20, 4.21, 4.22, 4.23 are shown the image of spot welded nugget capture by image analyzer. There are different image produced when changing the parameter. Figure 4.20 shown the value of strength decreasing compare to the figure 4.21, the nature of result different from before. This is because excessive heats occur in figure 4.20. That why the value of strength for 1.2mm thickness is decreasing as shown in figure 4.20. Once increasing the welding time, heat of the effected zone increasing too. But, if excessive heats occur the strength of spot welded nugget will be decrease. There is mostly difference from before which the highest strength of the spot welded for 1.5mm thickness specimen is higher than 1.2mm in thickness specimen. But the lowest value of strength is located at the same condition like before which the strength of spot welded for 1.2mm thickness specimen greater than 1.5mm thickness specimen. From the observation of the specimen while the specimen was tested, it observed that excessive heat energy input causes void and crack formation, partially spurt out of molten metal and so, the strength of joining decreases for 1.2mm thickness specimen. This clearly shows that the sheet metal with 1.5mm in thickness more suitable in this welding condition.

4.4 THE ULTIMATE STRENGTH OF MATERIAL

An important element to be considered by a designer is how the material that has been selected will behave under a load. This is determined by performing specific tests on prepared samples of the material. A test specimen of mild steel will be prepared and placed in a laboratory testing machine to be subjected to a known centric axial tensile force. As a magnitude of the force is increased, various changes in the specimen are measured such as changes in length and its diameter. Eventually the largest force which may be applied to the specimen is reached, and the specimen either breaks or begins to carry less load. This largest force is called the ultimate load for the test specimen. Since the applied load is centric, we may divide the ultimate load by the original cross sectional area to obtain the ultimate normal stress of the material used. In this experiment the cross sectional area is same for all specimen. But, there is no effect to the strength of the spot welded nugget.

4.5 MILD STEEL SHEET CHARACTERISTIC

From observation of the tensile testing, the specimen subjected to tension first undergoes uniform elongation, and that when the load exceeds the ultimate tensile strength of the material, the specimen begins to neck and thus elongation is no longer uniform.

The true strain at which necking begins is equal numerically to the strain hardening exponent (n). Thus a high ‘n’ value indicates large uniform elongation. Necking may be localized or it may be diffuse, depending on the strain rate sensitivity (m) of the material. The higher the value of ‘m’, the more diffuse the neck becomes.

Figure 4.24: Failure on spot welded

Figure 4.24 shown the low carbon steel exhibit a behavior called yield point elongation having both upper and lower yield points. This behavior results in Luder's bands or also called stretcher strain marks or worms on the sheet. These are elongated depression on the surface of the sheet, such as can be found on the bottom of cans containing common household products.

4.6 FRACTURE CRITERIA FOR BRITTLE MATERIAL

Mild steel is brittle material, which brittle material is characterized by the fact that, when subjected to a tensile test, they fail suddenly through rupture or fracture without any prior yielding. When a structural element or machine component made of a brittle material is under unaxial tensile stress, the value of the normal stress that causes it to fail is equal to the ultimate strength of material as determined from a tensile test, since both the tensile test specimen and the element or component under investigation are in the same state stress. However, when a structural element or machine component is in a state of plane stress, it is found convenient to first determine the principal stresses at any given point, and the criteria indicated to predict whether or not the structural element or machine component will fail.

4.7 HEAT EFFECTED ZONE

The heat affected zone (HAZ) is within the base metal itself. It has a microstructure different from that of the base metal prior to welding, because it has been subjected temporarily to elevated temperatures during welding. The portion of the base metal that are far enough away from the heat source do not undergo any structural changes during welding because of the far lower temperature to which they are subjected.

The properties and microstructure of the HAZ depend:

- On the rate of heat input and cooling
- The temperature to which this zone was raised

- Metallurgical factors such as original grain size, grain orientation, and degree of prior cold work
- Physical properties such as the specific heat and thermal conductivity of the metals

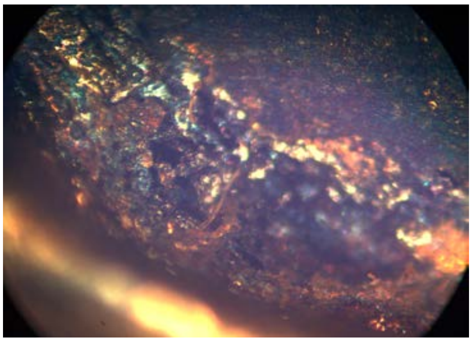


Figure 4.25: Excessive Heat affected zone

The strength and hardness of the heat affected zone depend the partly on how the original strength and hardness of the base metal was developed prior to the welding. On the other hand, grains close to the weld metal have been subjected to elevated temperatures for a longer period of time such at 5A welding current and 4sec welding time condition for 1.2mm in thickness as shown in figure. Consequently, the grains will grow in size and this region will be softer and have lower strength. Such a joint will be weakest at its heat affected zone.

4.8 INCOMPLETE FUSION, PENETRATION AND CRACK

Incomplete fusion (lack of fusion) produces poor weld beads. A better weld can be obtained by the use of the following practices:

- Raising the temperature of the base metal
- Cleaning the weld area before welding
- Changing the type of electrode used

Incomplete penetration occurs when the depth of the welded joint is insufficient. Penetration can be improved by the following practices:

- Increasing the heat input
- Ensuring that the surfaces to be joined fit each other properly

Figure 4.26: Crack during spot welding process

In this experiment the cracks occur at 5A welding current and 4sec welding time condition for 1.2mm in thickness as shown in figure. Crack may occur in various location and directions in the weld area. Crack also is classified as hot cracks that occur while the join is still at elevated temperatures and cold cracks that develop after the weld metal has solidified. The basic crack prevention measures in these welding are the following:

- Decrease the welding time
- Decrease the welding current
- Increase the thickness of sheet metal

These parameters always influence the strength in the spot welding. Nice point of spot welded will produce high strength of spot welded joint.

4.9 EFFECT IN SPOT WELDING PROCESS

There are nine main effects in spot welding process. A little changing in parameter cause obvious changing on the strength of spot welded joining

1. Effect of environment
2. Effect of welding current
3. Effect of welding time
4. Effect of electrode tips
5. Effect of pressure
6. Effect of heat generation
7. Effect of heat balance
8. Effect of nugget area
9. Effect of mild steel

Each of these effects is explained clearly below:

4.9.1 Effect of Environment

Normally, the surface appearance of a spot weld should be relatively smooth, round or oval in the case of contoured work, and free from surface fusion, electrode deposits pits, cracks and deep electrode indentation. All metals develop oxides which can be detrimental to resistance spot welding. Some oxides, particularly those of a refractory nature, are more troublesome than others. In addition, the mill scale found on hot-rolled steels will act as an insulator and prevent good quality resistance spot welding. Surfaces to be joined by this process should be clean, free of oxides, chemical compounds, and have a smooth surface. The smooth weld surface appearance is almost obtained for all of the welded materials in this study.

4.9.2 Effect of Welding Current

Figure shows the effect of welding current on the spot-welded joints, the figure illustrating that an increase in the welding current leads to an increment in the strength of joining. This may be attributed to the increase in the amount of heat developed. But once excessive in heat energy input causes void and crack formation, partially spurt out of molten metal and so, the tensile strength of joint decreases.

4.9.3 Effect of Welding Time

Resistance spot welding depends on the resistance of the base metal and the amount of current flowing to produce the heat necessary to make the spot weld. Another important factor is time. In most cases several thousands of amperes are used in making the spot weld. Such amperage values, flowing through a relatively high resistance, will create a lot of heat in a short time. To make good resistance spot welds, it is necessary to have close control of the time the current is flowing. Actually, time is the only controllable variable in most single impulse resistance spot welding applications. Current is very often economically impractical to control. It is also unpredictable in many cases.

Most resistance spot welds are made in very short time periods. Since alternating current is normally used for the welding process, procedures may be based on a 60 cycle time (sixty cycles = 1 second). Previously, the formula for heat generation was used. With the addition of the time element, the formula is completed as follows:

$$\mathbf{H = I^2RTK} \tag{4.1}$$

Where:

H = Heat

I^2 = Current Squared

R = Resistance

T = Time

K = Heat Losses

Control of time is important. If the time element is too long, the base metal in the joint may exceed the melting (and possibly the boiling) point of the material. This could cause faulty welds due to gas porosity. There is also the possibility of expulsion of molten metal from the weld joint, which could decrease the cross section of the joint weakening the weld. Shorter weld times also decrease the possibility of excessive heat transfer in the base metal. Distortion of the welded parts is minimized, and the heat affected zone around the weld nugget is substantially smaller.

4.9.4 Effect of Electrode Tips

Copper is the base metal normally used for resistance spot welding tongs and tips. The purpose of the electrode tips is to conduct the welding current to the workpiece, to be the focal point of the pressure applied to the weld joint, to conduct heat from the work surface, and to maintain their integrity of shape and characteristics of thermal and electrical conductivity under working conditions. Electrode tips are made of copper alloys and other materials. The Resistance Welders Manufacturing Association (RWMA) has classified electrode tips into two groups:

Group A − Copper based alloys
Group B − Refractory metal tips

In this experiment, Group A was used to conduct the spot welding machine. Group A, Class I electrode tips are the closest in composition to pure copper. As the Class Number goes higher, the hardness and annealing temperature values increase, while the thermal and electrical conductivity decreases.

4.9.5 Effect of Pressure

The effect of pressure on the resistance spot weld should be carefully considered. The primary purpose of pressure is to hold the parts to be welded in intimate contact at the joint interface. This action assures consistent electrical resistance and conductivity at the point of weld. The tongs and electrode tips should not be used to pull the workpieces together. The resistance spot welding machine is not designed as an electrical “C” clamp! The parts to be welded should be in intimate contact before pressure is applied.

Investigations have shown that high pressures exerted on the weld joint decrease the resistance at the point of contact between the electrode tip and the workpiece surface. The greater the pressure the lower the resistance factor. Proper pressures, with intimate contact of the electrode tip and the base metal, will tend to conduct heat away from the weld. Higher currents are necessary with greater pressures and, conversely, lower pressures require less amperage from the resistance spot welding machine. The pressure exerted by the tongs and the electrode tips on the workpiece have a great effect on the amount of weld current that flows through the joint. The greater the pressure, the higher the welding current value will be, within the capacity of the resistance spot welding machine. This fact should be carefully noted particularly when using a heat control with the various resistance spot welding machines.

4.9.6 Effect of Heat Generation

Figure shows the effect of welding time on the spot-welded joints, the figures indicating that increasing the welding time leads to an increment in the strength of joining. This may be attributed to the increase in the amount of heat developed *Q*:

$$\mathbf{Q = I^2RT} \qquad \mathbf{(4.2)}$$

Where:

I = welding current

R = sheet resistance

T = welding time

The secondary portion of a resistance spot welding circuit, including the parts to be welded, is actually a series of resistances. The total additive value of this electrical resistance affects the current output of the resistance spot welding machine and the heat generation of the circuit. The key fact is, although current value is the same in all parts of the electrical circuit, the resistance values may vary considerably at different points in the circuit. The heat generated is directly proportional to the resistance at any point in the circuit.

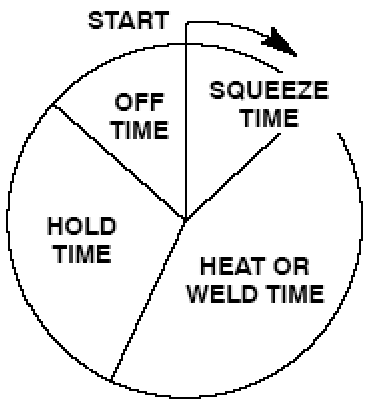


Figure 4.27: Spot Welding Time Cycle

HEAT OR WELD TIME − Weld time is cycles.
SQUEEZE TIME − Time between pressure application and weld.
HOLD TIME − Time that pressure is maintained after weld is made.
OFF TIME − Electrodes separated to permit moving of material for next spot.

The resistance spot welding machines are constructed so minimum resistance will be apparent in the transformer, flexible cables, tongs, and electrode tips. The resistance spot welding machines are designed to bring the welding current to the weldment in the most efficient manner. It is at the weldment that the greatest relative resistance is required. The term “relative” means with relation to the rest of the actual welding circuit. There are six major points of resistance in the work area. They are as follows:

1. The contact point between the electrode and top workpiece.
2. The top workpiece.
3. The interface of the top and bottom workpieces.
4. The bottom workpiece.
5. The contact point between the bottoms workpiece and the electrode.

6. Resistance of electrode tips.

The resistances are in series, and each point of resistance will retard current flow. The amount of resistance at point 3, the interface of the workpieces, will depend on 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.This heat anneals and removes the residual stresses from the spot-welded joints and consequently increases the strength.

4.9.7 Effect of Heat Balance

There is no particular problem of heat balance when the materials to be welded are of equal type and thickness. The heat balance, in such cases, is automatically correct if the electrode tips are of equal diameter, type,etc. Heat balance may be defined as the conditions of welding in which the fusion zone of the pieces to be joined are subjected to equal heat and pressure.

When the weldment has parts of unequal thermal characteristics, such as copper and steel, a poor weld may result for several reasons. The metals may not alloy properly at the interface of the joint. There may be a greater amount of localized heating in the steel than in the copper. The reason would be because copper has low electrical resistance and high thermal transfer characteristics, while steel has high electrical resistance and low thermal transfer characteristics. So there is no problem of heat balance in this experiment, because use equal type and same thickness of material.

4.9.8 Effect of Nugget Area

When consider that it is through the electrode that the welding current is permitted to flow into the workpiece, it is logical that the size of the electrode tip point controls the size of the resistance spot weld. Actually, the weld nugget diameter should be slightly less than the diameter of the electrode tip point. If the electrode tip diameter is too small for the application, the weld nugget will be small and weak.

If, however, the electrode tip diameter is too large, there is danger of overheating the base metal and developing voids and gas pockets. In either instance, the appearance and quality of the finished weld would not be acceptable.

To determine electrode tip diameter will require some decisions on the part of the weldment designer. The resistance factors involved for different materials will certainly have some bearing on electrode tip diameter determination. A general formula has been developed for low carbon steel. It will provide electrode tip diameter values that are usable for most applications.

The formula generally used for low carbon steel is as follows:

Electrode tip diameter = 0.100” + 2t **(4.3)**

Where “t” is the thickness in inches of one thickness of the metal to be welded. This formula is applicable to the welding of metals of dissimilar thicknesses. The formula is applied to each thickness individually, and the proper electrode tip diameter selected for each size of the joint.

For example, if two pieces were equal in thickness of 1.2mm and 1.5mm sheet metal is to be joined, the electrode tip diameter would be the same for both sides of the joint. The calculation would be as follows:

- For thickness = 1.2mm
  t =1.2mm = 0.047”

From equation:

Electrode tip dia. = 0.100” + 2(0.047”)
= 0.194”

- For thickness = 1.5mm
  t =1.5mm = 0.059”

From equation:

Electrode tip dia. = 0.100” + 2(0.059”)
= 0.218”

Figure 4.28: Sample of Electrode Tip Diameter

Figure shows the correlation between the failure load and the nugget area, with respect to the welding current, welding time and the sheet thickness. The figure indicates that the nugget area increases when the welding current increases. When the nugget area increases, the failure load increases in a linear correlation.

4.9.9 Effect of Mild Steel

Mild or low-carbon steel comprises the largest percentage of material welded with the resistance spot welding process. 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. Hot rolled steel will normally have mill scale on the surface of the metal. This type of material is usually not resistance spot welded with resistance welding machines of the KVA ratings of specific built units.

If the oil concentration is excessive on the sheet metal, it could cause the formation of carbon at the electrode tips thereby decreasing their useful life. Degreasing or wiping is recommended for heavily oiled sheet stock.

The resistance spot weld should have shear strength equal to the base metal shear strength and should exceed the strength of a rivet or a fusion plug weld of the same cross sectional area. Shear strength is normally accepted as the criteria for resistance spot weld specifications, although other methods may be used.

With magnetic materials such as mild steel, the current through the weld can vary substantially depending on how much of the magnetic material is within the tong loop. The tong loop is sometimes called the “throat” of the resistance spot welding machine. For example, the part to be welded may have the largest amount of the base metal within the throat of the unit for any one resistance spot weld and almost none of the base metal in the throat for the second spot weld. The current at the weld joint will be less for the first weld. The reason is the reactance caused by the ferrous material within the arc welding circuit.

In any material being resistance spot welded, there is the possibility of shunt currents flowing through the previously made spot welds. This can rob the second spot the second spot weld of the welding current necessary for making the joint.

Resistance spot welding machines are applicable to low carbon steel welding. They must be used within their rated capacity of total thickness of material for best results. They should not be used over the duty cycle since damage to the contactor and transformer may result. The 50 percent duty cycle provided for this type of equipment should be adequate for all applications within their rating. The 50 percent duty cycle is a RWMA standard rating for general duty resistance welding machines. The 50 percent duty cycle is based on a 10 second time period and means the unit can weld 5 seconds out of each 10 second time period.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 INTRODUCTION

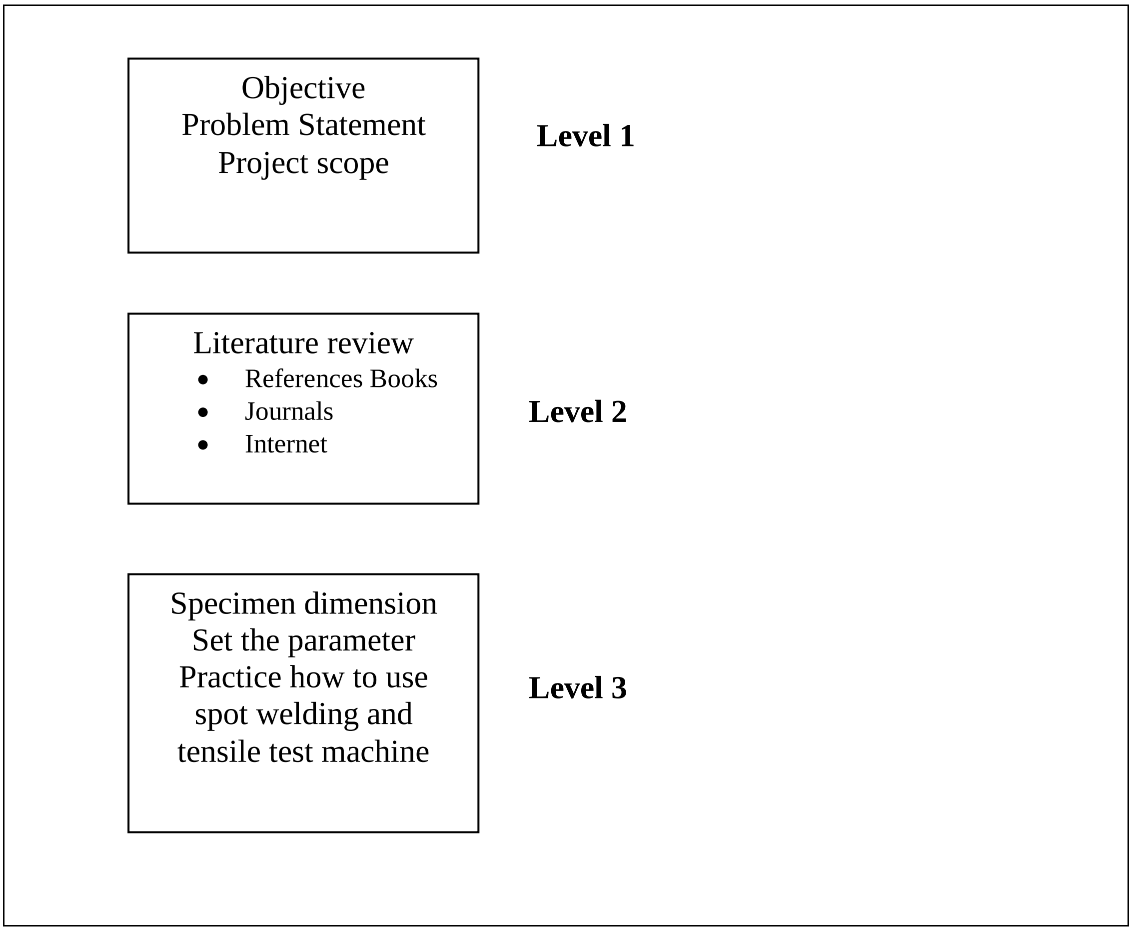
Chapter 5 is the last chapter in this thesis writing. In this chapter, the whole conclusion of this project that has been carried out in last two semesters will be discussed

5.2 ACCOMPLISHMENT

In general, the accomplishment of spot welded experimental can be divided into two parts. In part one, it consist of literature review and methodology that have been done during semester one. In the part two, it consists of spot welding process, tensile testing process and analyzes the data that have been done during second semester.

5.2.1 PART 1

In first part, the tasks are divided into several steps as shown in figure below.

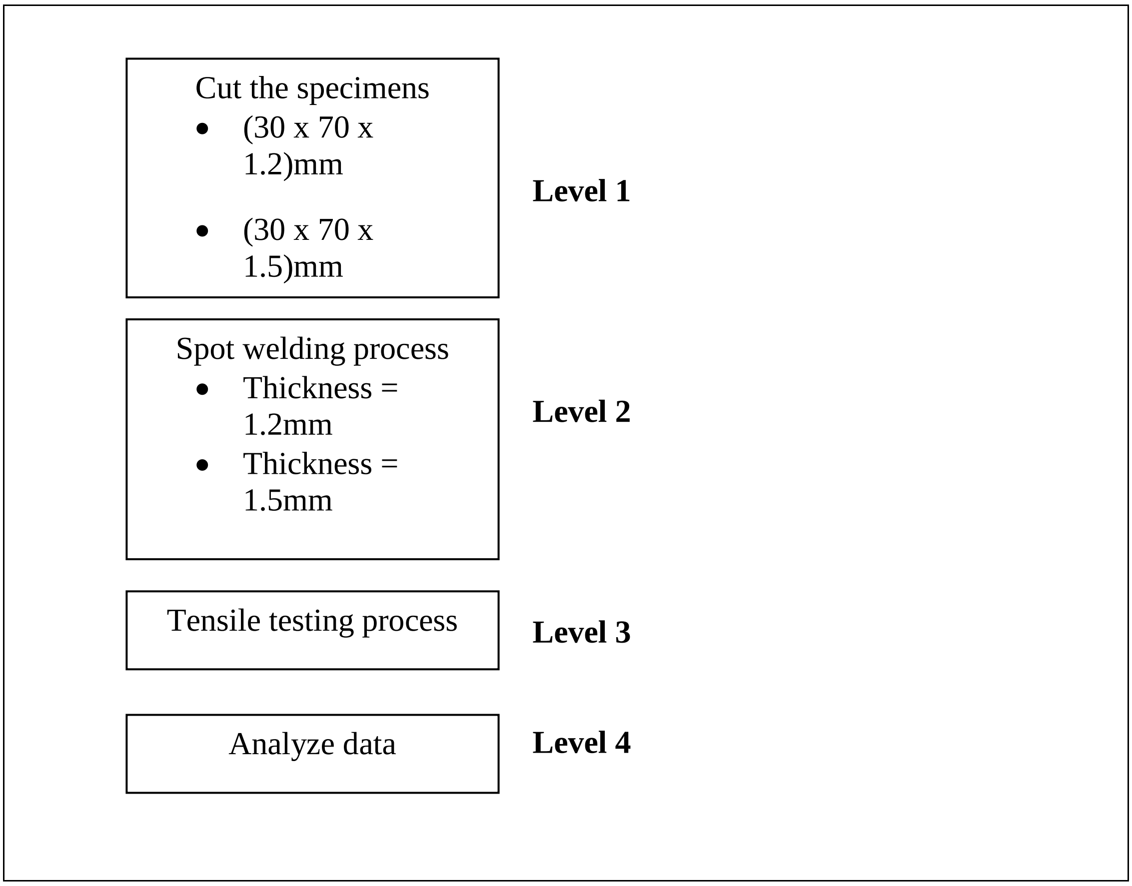


In first level, research on strength of spot welded has been done. All the information about the objectives, problem statements and project scopes has been discussed in chapter 1. In the chapter 1, the thesis is about introduction about the spot welding, tensile test and about accomplishment of the whole project concluded into Gantt chart. The objectives of chapter 1 are to give a general overview of the project to the reader.

In the second level, the writings are about literature review that has been carried out. The main purpose of this literature review is to get information about the project from the references book, magazines, journals, technical papers and web sites, where it helps me to generate ideas on new design. In this chapter, all the in formations that have been gathered discussed briefly. Three of them were about the procedure of welding process, procedure of tensile testing process and how to analyze the data.

In third level, discussion about the parameters of spot welding in term of welding time, welding current, and diameter of electrode to control on this experiment. After all the studies, the sheet metal specimen dimensioned and tries practice how to use spot welding and tensile test machine.

5.2.2 PART 2



The second part of project started with cutting specimen. Dimension of sheet metal are (w = 30, L = 70, T = 1.2) mm and (w = 30, L = 70, T = 1.5) mm. Seventy two sheet metal for each dimension are prepared using stamping machine. Total of all sheet metal is about 144 sheets.

After that all of the sheet joint by using spot welding machine by overlapping joint. Total of specimen is about 72 sheets. The tensile test machine is conducted to measure value of strength for each specimen. After all the data were collected, maximum load vs weld current and maximum load vs weld time relationship were plotted to analyze the data.

5.3 CONCLUSION

Resistance spot welding is a welding technique that is used for almost all known metals. The actual weld is made at interface of the parts to be joined. The electrical resistance of the material to be welded causes a localized heating at the interfaces of the metals to be joined. Welding procedures must be developed for the most satisfactory. Tensile-shear test were applied to the welded specimens. Increasing of the Nugget diameter increases tensile-shear strength of the spot welded joint, since the load carrying cross-section widens.

The heat that building during the welding process is proportional to time and square of current. The size of the weld nuggets is increasing due to increasing the weld current and weld time. High welding current and high welding time will produce high strength of joining. But more thickness of specimen will produce lower strength. The optimum parameter are at condition (T = 1.2mm, t = 3sec & I =5A) which produced 5.958kN of loading. Excessive heat input cause crack formation and will reduce the strength of joining.

In spot welding process, if welding current is increased, welding time should be decreased because to prevent excessive heat input. Once excessive heat input, the crack formation will be occur and straight away destroy the weld nugget. As a result, the strength of the joining will be reducing. As conclusion, small change of parameters in spot welding process will effect on joining strength.

5.4 RECOMMENDATION

The strength of spot welded can be expanded due to other factors. There are several factors must be considered to improve the joining strength of spot welded such as:

- Do surface finishing process to throw up the corrosion before start welding process
- Use flat specimen to make sure intimate contact between piece to prevent heat input loss during welding process
- Use advance spot welding machine which can determine and control various parameters

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APPENDIX

Sample Result of Tensile Test for Thickness = 1.2mm

Series IX version 8.33.00 Version date: 18 Jan 2005

Sample ID: I=5A,t=4sec Test Date: 13 Aug 2008

Test Type: Tensile Method: 1

Operator Name: spot weld Edit date: -------

Units: SI Geometry: Rectangular

Number of specimens: 1 Number of channels: 2

Machine type: ------- Machine Control: STANDARD

Data Rate: 1.000000 pts/sec Extensometer: Disabled

Crosshead Speed: 1.00000 mm/min

Temperature: 27 Deg C Humidity: 50 %

Auto-start: Disabled Separate dimension entry: Enabled

Specimen: 1

Test end reason: Crosshead was stopped

Width: 30.0000000 mm

Thickness: 1.2000000 mm

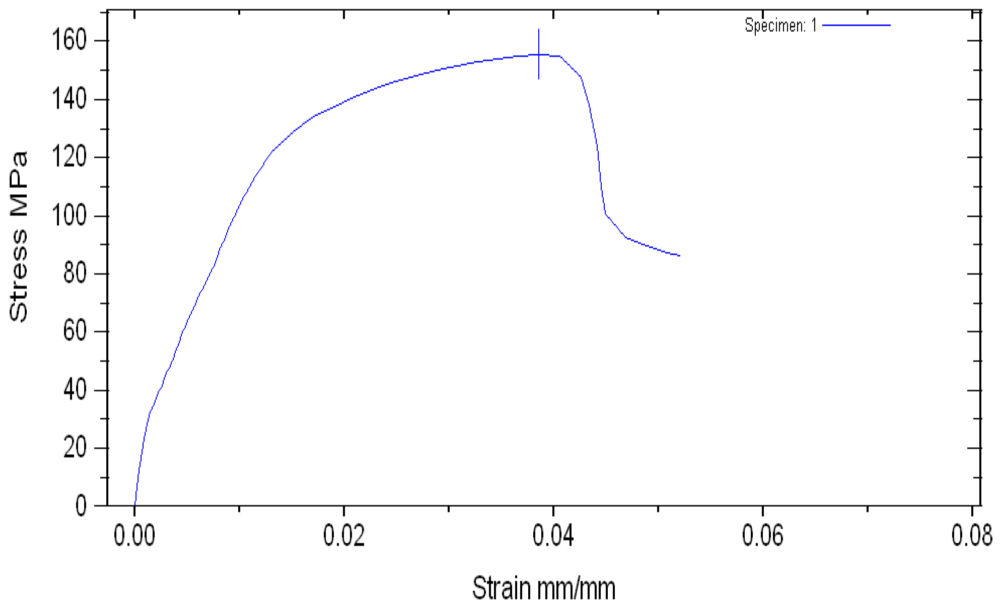
Spec gauge len: 85.0000000 mm

Ext. gauge len: 30.0000000 mm

Number of data points: 80

Maximum Load point: 70 Maximum Load: 5.78000 kN

Maximum Extension point: 80 Maximum Extension: 4.431 mm



The graph Stress against Strain

Sample Result of Tensile Test for Thickness = 1.5mm

Series IX version 8.33.00 Version date: 18 Jan 2005

Sample ID: I=2A,t=4 Test Date: 15 Aug 2008

Test Type: Tensile Method: 1

Operator Name: spot weld Edit date: -------

Units: SI Geometry: Rectangular

Number of specimens: 1 Number of channels: 2

Machine type: ------- Machine Control: STANDARD

Data Rate: 1.000000 pts/sec Extensometer: Disabled

Crosshead Speed: 1.00000 mm/min

Temperature: 27 Deg C Humidity: 50 %

Auto-start: Disabled Separate dimension entry: Enabled

Test end reason: Crosshead was stopped

Width: 30.0000000 mm

Thickness: 1.2000000 mm

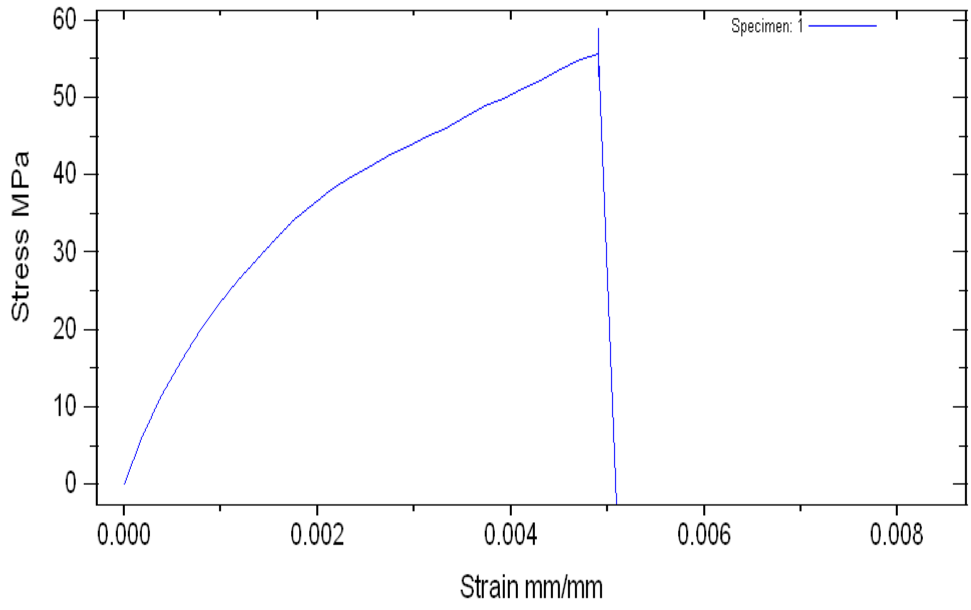
Spec gauge len: 85.0000000 mm

Ext. gauge len: 30.0000000 mm

Number of data points: 30

Maximum Load point: 26 Maximum Load: 1.503 kN

Maximum Extension point: 30 Maximum Extension: 0.47781 mm



The graph Stress against Strain