TAGUCHI METHOD IN DETERMINIG THE OPTIMUM SPOT WELDING PARAMETERS FOR AUTOMOTIVE COMPONENT

MOHD AKRAM BIN CHE OMAR

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ABSTRACT

Resistance spot welding (RSW) is used for the fabrication of sheet metal assemblies. The process is used widely in the automotive structural application for many years in joining low carbon or "mild" steel. The mild steel also used for the unibody collision repair for the car body [1]. The major advantages of spot welding are high speed and adaptableness for automation in high-volume and/or high-rate production. Despite these advantages, the determination of appropriate welding parameters for spot welding is a very complex matter. A small change of one parameter will influence all the other parameters. For example the different combination value of each of the parameters above will produce the different toughness of weld joining. The welding process is depending on the thickness and the condition of the material to be weld and the kind of the welding apparatus uses [2].

In this study, the Taguchi method is used to determine the optimum spot welding parameters for automotive component, the mild steel or low carbon steel is used in this study. For this study, mild steel with the thickness of 1 mm, 70 mm length and 30mm width will be used as a work pieces. Two work pieces with the same thickness, length and width will be joint using the resistance spot welding. The strength of the joining will be tested using the tensile test machine, an orthogonal array (OA), main effect, single – to – noise (S/N) ratio and analysis of variance (ANOVA) are applied in order to investigate the optimal spot welding parameters when different level of parameters are used to weld the work piece. From this study also the main parameters that affect the performance of the spot welding can be determined

ABSTRAK

Teknologi kimpalan "spot welding" umumnya digunakan dalam proses kimpalan untuk mencantumkan kepingan logam.Teknologi ini digunakan secara meluas dalam industri pembuataan automotif dalam mencantum bahagian komponen kenderaan, teknologi ini juga turut digunakan dalam kerja-kerja pembaik-pulih badan kenderaan (kereta).Kelebihan teknologi "spot welding"ini adalah kebolehan mengimpal dengan kadar yang pantas dan dalam industri automotif, ia mampu mengimpal sejumlah besar komponen kenderaan dalam jangka masa yang singkat.Disebalik keberkesanaanya, penentuaan penggunaan parameter yang sesuai untuk proses "spot welding" adalah suatu yang rumit.Perubahan kecil dalam satu-satu parameter akan memberi kesan kepada keseluruhan parameter yang lain.Ini kerana perbezaan nilai pada parameter akan menghasilkan kekuatan kimpalan yang berbeza.Proses kimpalan adalah bergantung kepada ketebalan, jenis bahan dan peralatan untuk kimpalan.

Untuk kajian ini, "Taguchi Method" digunakan dalam menentukan kombinasi yang paling optimum di antara parameter yang digunakan untuk mengimpal komponen pada bahagian kenderaan, logam jenis "mild steel" digunakan dalam kajian ini.Logam yang berukuran 1mm tebal, 70 mm panjang dan 30 mm lebar digunakan sebagai bahan uji kaji.Kedua-dua kepingan logam yang mempunayai ukuran yang sama disambung dengan mengunakan proses kimpalan tersebut.Kekuatan camtuman tersebut kemudianya diuji mengunakan sejenis mesin "tensile test",kemudiannya kaedah "orthogonal array (OA)", "main effect", "single – to – noise (S/N) ratio" and "analysis of variance (ANOVA)" digunakan dalam menentukan kombinasi optimum yang terhasil jika setiap parameter itu mengunakan nilai yang berbeza ketika mengimpal kepingan logam tersebut.Melalui kajian ini juga, parameter yang akan memberi kesan kepada kekuatan atau keberkesanan sesuatu kimpalan turut dapat ditentukan.

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H	= Heat is generated in joules (watt- second)
I	= Current (in amperes)
R	= Resistance (in ohms)
t	= Time to current flow (in seconds)
L_9 (3^4)	= L –Level 9 – Number of experiment (9 experiment) 3 – There are 3 level used in this experiment 4 – Number of parameters (4 parameters)
RSW	= Resistance Spot welding
A	= Electrode force
B	= Weld time
C	= Squeeze time
D	= Weld current
S/N analysis	= Signal to noise ratio analysis
DOE	= Design of Experiment
ANOVA	= Analysis of Variance

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CHAPTER 1

INTRODUCTION

1.1 Background

Resistance spot welding (RSW) is among the oldest of the electric welding method that used in the industry and it is useful and accepted method in joining metal. The spot welding is widely used in welding carbon steel because they have higher electrical resistance and lower thermal conductivity than the electrode that made from copper. The spot welding is commonly being used in automobile industry, where it is used to weld the sheet metal forming a car. Spot welders can also be completely automated, and many of the industrial robots found on assembly lines are spot welders [2]. Spot welding also being used in the repair industry, for example in Europe and Japan the resistance spot welding has been used in unibody collision repair industry [1].

The spot welding have its own parameters .This parameters will determine the quality of the welds. The appropriate combination of the spot welding parameter will produce strong joining and good quality of welding. Spot welding parameters include [7]:

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

1.2 Objective

1. To evaluate the performance of spot welding with respect to various spot welding parameters such as electrode force, weld time, squeeze time and weld current.
2. Taguchi method is used in order to analyze and determined the optimal parameters of spot welding.

1.3 Scope

1. The work piece that used is mild steel
2. Parameters to be studied in spot welding are electrode force, weld time, squeeze time and weld current.
3. The toughness of the joining parts will be determined using tensile test machine.
4. The Taguchi method and Analysis of variance (ANOVA) method will be analyzed using Minitab 15 Statistical Software.

1.4 Problem Statement

The determination of appropriate welding parameters for spot welding is a very complex matter. A small change of one parameter will influence all the other parameters. For example the different combination value of each of the parameters above will produce the different toughness of weld joining. The welding process is depending on the thickness and the condition of the material to be weld and the kind of the welding apparatus uses [2].

For this experiment the parameters that will be used are electrode force, weld time, squeeze time and weld current. The tensile test is used to test the strength of the joining that is done by combining different combination of spot welding parameters value. The result for each test is taken and the optimum combination for the spot welding parameters can be determined. For this project the Taguchi method will be used in determined the optimum spot welding parameter value.

1.5 Flow Chart

This flow chart shows the stages of process to complete this project. All the stages are shown in Figure 1.5

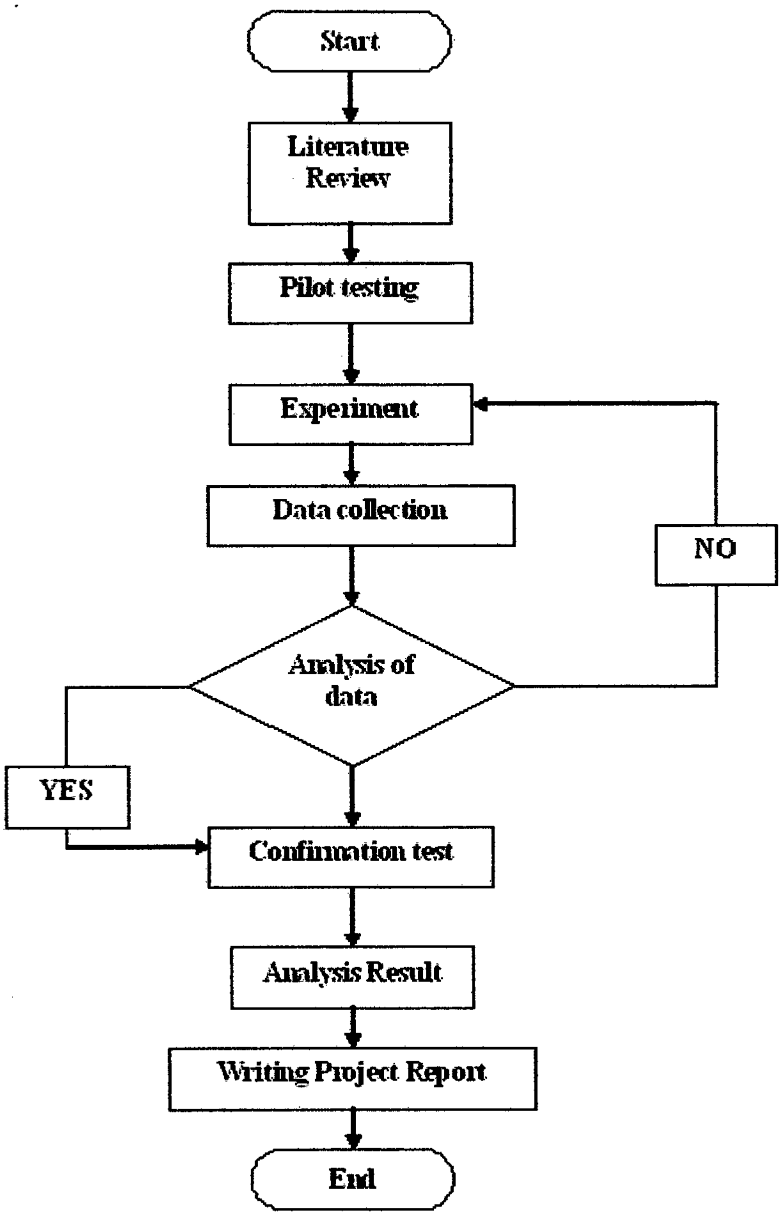


Figure 1.5 Flow chart

CHAPTER 2

LITERATURE STUDY

2.1 Principle of Operation for Resistance Spot Welding

Resistance Spot Welding (RSW) is included in the group of resistance welding processes that heat is used in joining the work parts of metal [4]. Heat is generated from electrical resistance across the two work parts (as shown in figure 2.1). In Resistance Spot Welding two work part of metal are joined together by applying electric current and pressure in the zone to be weld and resistance welding is different from arc welding because its not required filler metal or fluxes added to the weld area during the welding process.

Spot welding operates based on four factors that are [2]:

1. Amount of current that passes trough the work piece.
2. Pressure that the electrodes applied on the work piece.
3. The time the current flow trough the work piece.
4. The area of the electrode tip contact with the work piece.

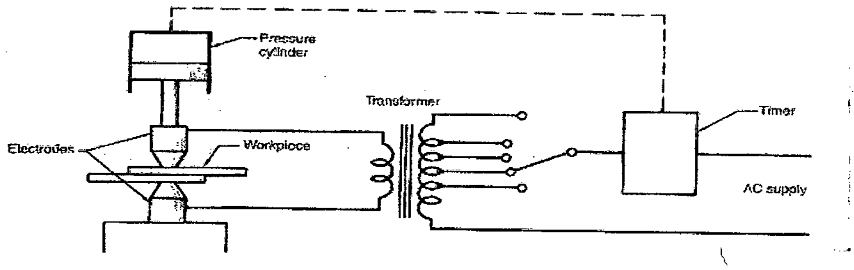


Figure 2.1 Fundamental resistance welding machine circuits [1].

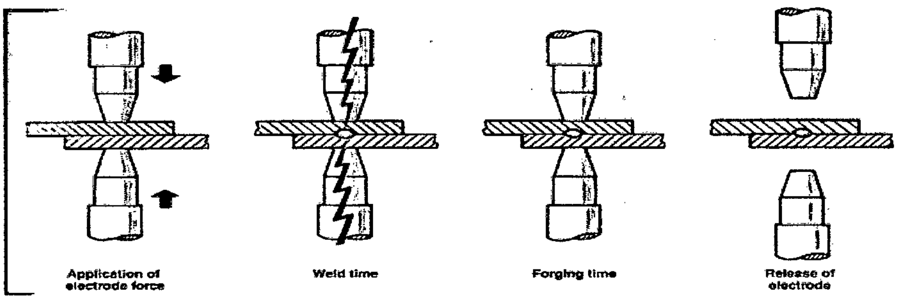


Figure 2.2 Basic period of Spot welding [1]

During the welding process the amount of electric current is flow from the electrodes to the work pieces (as shown in figure 2.2). The weld force is applied by squeezing the electrode to the work pieces, the right amount of pressure that applied on the work pieces is very important in order to obtain the good quality of welds. During the welding process, the 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, 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 [2,3].The heat that generated in spot welding is basically depend on the electric current and the time being used and on the electrical resistance of material between electrodes [4] .

The heat that generates in resistance spot welding according to Joule's law is expressed by the Equation 2.0, where [2]:

$$H = I^2 R t \tag{2.0}$$

But for the practical purpose a factor K (heat loss) should be include. Then the actual resistance welding is expressed by the Equation 2.1 [2]:

$$H = I^2 R t K \tag{2.1}$$

Where:

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

I = Current (in amperes)

R = Resistance (in ohms)

t = Time to current flow (in seconds)

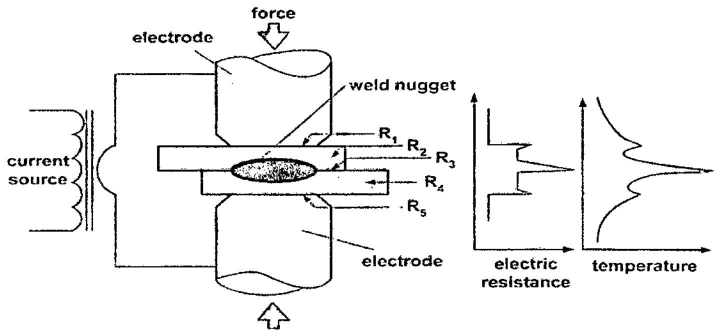


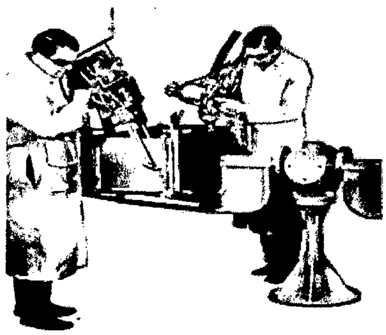
Figure 2.3 Electrode – work – piece interface resistance – R1 and R5; resistance of the work- pieces – R2 and R4; resistance in the interface between works – pieces- R3 [4]

The heat generated depends on the electrical current and time being used and on the electrical resistance. The electrical resistance is composed by five separated resistance, as show in figure 2.3. Resistance at R1 and R5 are unwanted because they produce heating and if the heat is too great it will damage 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. The amount of heat generated is reducing in the work- pieces that have low resistance, so it is difficult to weld. Resistance at R3 will determine the nuggets deformation [4].

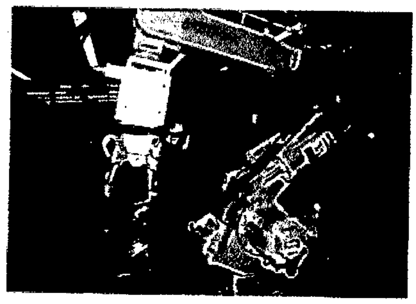
The nugget is a melted material that forms in the interface of work-pieces with a diameter similar to sizes of those electrodes, as show in the figure 2.3. The penetration for nugget should be at least 20 % of the thinnest sheet member but not exceeding 80% of the same thickness [6]. The current that transfer after the application of force by electrodes 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 [4].

Resistances spot welding machine that operate automatically (refer to Figure 2.4 (b)) can be handle by amateur worker or operator because good- quality welds made on rocker arms or press machine depend on proper adjustment and setup of the equipment. When handling the portable welding machine such as potable gun machine (refer to Figure 2.4(a)) the skill is become priority in order to get good-quality welds. 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 [2].

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 suitable for welding many parts of unibody's thin-gauge area that need good strength and no distortion [1]



(a)



(b)

Figure 2.4: (a) Manual portable spot welding gun [1]

(b) Portable spot welding gun on robot (Automatic) [1]

2.2 Parameters for Resistance Spot Welding.

For the welding parameters according to Joule's law are time, 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 [4].The parameters that can be controlled in the welding machine are current, time and force [4].

Generally, these are the Spot welding parameters [7]:

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

For this project only four parameters are selected and going to be study, they are electrode force, weld time, squeeze time and weld current. To get a better understanding of the parameters that going to be used for this study, below are the briefly explanation on the parameters;

i. Electrode Force

The purpose of the electrode force is to squeeze the parts to be weld and the primary purpose is to hold the parts to ensure the parts in intimate contact at the joining interface [6]. 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 [1]. This means that the higher electrode force requires a higher weld current.

Weld spatter can be happen because the pressure on the tips is too light or when weld current becomes too high. Too 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 [1].

ii. 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.

Normally low percent current settings are not recommended because it may harm 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 current becomes too great internal spatter will result.

iii. 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 [7].Most of the processes that using resistance spot welding is done in very short time. The time period for spot welding is usually based on 60 – cycle time (60 cycles in one second) [1].It is difficult to determine the exact value of the optimum weld time because of a few uncertainties such as [7]:

- 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 [7].