EXPLORING THE FAILURE MODE AND MECHANICAL PROPERTIES OF SPOT WELDED DISSIMILAR JOINTS FOR AUSTENITIC STAINLESS AND GALVANIZED STEELS

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SUPERVISOR DECLARATION

"I hereby declare that I have read this thesis and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Design and Innovation)"

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This thesis is submitted to Faculty of Mechanical Engineering in partial fulfillment
of the requirement for the award of Bachelor's Degree in
Mechanical Engineering (Design and Innovation)

Faculty of Mechanical Engineering
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MAY 2013

DECLARATION

"I hereby declare that the work in this report is my own except for summaries and quotations which have been duly acknowledged."

Signature : …………………………

Author : THAM KAR MUN

Date : …………………………

For my beloved Mum and Dad

ACKNOWLEDGEMENTS

The success of this project depends largely on the encouragement and guidelines of many others. I would like to take this opportunity to express my gratitude to the people who have been instrumental in the successful completion of this report.

Firstly, I would like to express my outmost gratitude to my beloved supervisor, Dr. S. Thiru Chitrambalam. He guided me in different matters regarding my project. Furthermore, he had been very kind and patient while correcting my doubts. The supervision and support that he gave truly helped me in the progression and smoothness of my project. I appreciate his valuable information, suggestion and guidance along the process for completing this project.

In addition, I am equally grateful to my senior, Mr. Larry Long Yong Siang who was willing to spend his precious time helping me out and providing me ideas as well as advise whenever I faced any problem. Furthermore, I am very thankful to my friends, Mr. Hareshwara Ruban A/L Subramaniam, Mr. Tan Beng Hong, Mr. Sean John Matthew and Mr. Sivanyanam A/L Subramaniam. I am grateful to have their assistance, for me to have completed my tasks effectively and moreover on time.

Last but not the least, my thanks to all technicians from Faculty of Mechanical Engineering (FKM) and Faculty of Manufacturing (FKP) for their great commitment and cooperation during my experimental session in laboratory.

ABSTRAK

Kimpalan tertumpu austenit keluli tahan karat dan kepingan keluli bergalvani sedang digunakan secara meluas dalam industri pembuatan terutama untuk membina badan kereta. Hubungan antara setiap parameter serta hubungan antara parameter dengan sifat mekanik dan mod kegagalan tidak disiasat sepenuhnya dalam cara yang sistematik manakala teknik perubahan satu parameter dalam stau masa telah digunakan secara meluas. Oleh itu, usaha telah dijalankan pada AISI 304-2B austenit tahan karat dan JIS G3302 SGCC lembaran Galvanized Steel, berdasarkan Design of Experiment untuk mengkaji hubungan antara parameter kimpalan serta hubungan dengan tegangan muktamad tekanan dan mod kegagalan. Kajian ini dilakukan dengan mengadakan Screening Design untuk menentukan faktor-faktor utama di kalangan parameter yang ada. Faktor-faktor terrtentu kemudiannya digunakan dalam Response Surface Methodology untuk membangunkan satu model matematik bagi setiap response. Hasilnya menunjukkan bahawa weld current, weld time dan mempunyai kesan positif dengan ultimate tensile stress dan mod kegagalan manakala electrode force, hold time dan upslope mempunyai kesan negatif dengan kedua-dua responses.

ABSTRACT

The spot welding of Austenitic Stainless Steel and Galvanized steel sheet is being widely used in manufacturing industry especially for automobile body building. The inter relationship between the individual spot welding parameters of dissimilar joints as well as the inter-relationship between the parameters, which determine the mechanical properties and failure mode are somehow not fully investigated in a systematic way, while the ‘one parameter at a time’ technique has widely been used. Hence, an attempt was carried out on dissimilar joints between AISI 304-2B Austenitic Stainless and JIS G3302 SGCC Galvanized Steel sheet, based on the Design of Experiment methodology to study the inter relationships between the spot weld parameters as well as their relationship with ultimate tensile stress and failure mode. This study was done by conducting ‘screening design’ in order to determine the key factors among the available parameters. The selected key factors were then used by applying response surface methodology to develop mathematical models for each response. The result showed that the weld current, weld time and squeeze time have positive effects on ultimate tensile stress and failure mode while electrode force, hold time and upslope have negative effects on both the responses.

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LIST OF ABBREVIATIONS

UTeM	=	Universiti Teknikal Malaysia Melaka
FKM	=	Faculty of Mechanical Engineering
FKP	=	Faculty of Manufacturing
DOE	=	Design of Experiment
ANSI	=	American National Standard Institute
AWS	=	American Welding Society
SAE	=	Society of Automotive Engineers
RSW	=	Resistance Spot Welding
LSRSW	=	Low Scale Resistance Spot Welding
SSRSW	=	Small Scale Resistance Spot Welding
HAZ	=	Heat Affected Zone
NIST	=	National Institute of Standard & Technology
SEMATECH	=	Semiconductor Manufacturing Technology
FYP	=	Final Year Project
UTS	=	Ultimate Tensile Stress
FM	=	Failure Mode
EF	=	Electrode Force
WC	=	Weld Current
WT	=	Weld Time
HT	=	Hold Time
ST	=	Squeeze Time
US	=	Upslope
RSM	=	Response Surface Methodology
MT	=	Metal Tore failure
N	=	Nugget Pullout failure
WS	=	Weld Sheared failure

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CHAPTER 1

INTRODUCTION

1.1 Background

Joining of dissimilar metals by welding technologies has been widely utilized in engineering practice especially in the field of automotive. Other than arc welding, resistance spot welding is also been used as a joining process in the automotive industry. Dissimilar metal welding involves the joining of two or more different metals or alloys, and the most common type is the joining of stainless steel and non-stainless steel. However, there are difficulties in joining different steel sheet due to dissimilar thermal conductivity and electrical resistivity. Spot weld with dissimilar joint such as galvanized steel and austenitic stainless steel sheets are widely been used in constructing some part of vehicles body. In this study, galvanized steel sheets and austenitic stainless steel sheets were selected as materials to be spot welded.

Several studies and researches has been made, nevertheless, the studies focused on only controlling one parameter, commonly the welding current, in order to determine or to explore either the mechanical properties or failure mode or even both of the dissimilar joints (Marashi, et al., 2008) (Vural & Akkus, 2004) (Hasanbaşoğlu & Haçar, 2007) (Pouranvari, et al., 2008). However, Hayat (2011) also did a study which adjusts the parameter of weld time (Hayat, 2011).

A few studies have been published concerning the relationship between the weld control parameters and response variables of spot-welded dissimilar metal joints (Alenius, et al., 2006). Pre-welding is often been done to obtain suitable and optimum weld nugget diameter before proceed to investigate the fatigue strength as well as obtaining the S-N curve of the dissimilar joint (Vural & Akkus, 2006) (Vural, et al., 2006). The process parameters in spot welding are weld current, electrode force, hold time, squeeze time, weld time and upslope time.

1.2 Problem Statement

The determination of appropriate welding parameters for spot welding is a very complex issue particularly in dissimilar weld joints, which often needs multiple trial runs and skill in pre-determining the welding parameters, although generally not resulting in an optimum level. The inter relationships between spot welding parameters of dissimilar joints are somehow not fully investigated in a systematic way as most of the individual parameters interact each other and produce cumulative effects on the joint performance. For spot welded dissimilar joint between Austenitic Stainless steel and Galvanized steel, very limited published literature is only available.

1.3 Objectives

1. To investigate, study and record the relationship between the process variables with ultimate tensile stress and failure mode of spot welded dissimilar joint between Austenitic Stainless Steels and Galvanized Steels.
2. To develop mathematical models for prediction of responses of the spot welded dissimilar joint.

1.4 Scope

1. To study, understand the theory and relationship between the spot weld control parameters with ultimate tensile stress and failure mode of spot welded dissimilar joints between AISI 304-2B and JIS G3302 SGCC.
2. To apply design of experiments (DOE) methodologies to develop mathematical models for prediction of ultimate tensile stress and failure mode of spot welded dissimilar joint.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter introduced the basic knowledge of resistance welding and also resistance spot welding (RSW). Detail descriptions about RSW were shown in the aspect of welding cycle and process parameters. Furthermore, literature of tensile test and failure mode were also presented in this chapter.

2.2 Resistance Welding

Resistance welding is a process of joining by involving the fusion of metals. The phenomenon of this fusion is due to the electrical resistivity of the work pieces or metals which leads to the generation of heat. The three main factors in resistance welding which affects the weld quality are heat, pressure and time. Pressure indicates the electrode pressure exerted on the work piece. Pressure is applied before, during and also after the application of current to prevent arcing at the work piece. Heat generated at the faying surface is strongly related to the welding current applied and at the same time, the electrical resistivity of the work pieces. As the welding current passing to the work pieces, the resistance of electrical cause heat to be generated. Time is the weld time which the current is applied.

The combination of the following laws is thought to be useful in determining the amount of heat generated in resistance welding. The laws mentioned are the Ohm's Law and Joule's Law.

Ohm's Law states that:

$$V = IR \tag{2.1}$$

Joule's Law states that:

$$Q = IVt \tag{2.2}$$

Where:

V= voltage (V)

I= Current (A)

R= Resistance (Ω)

Q= Heat generated (J)

t= Time (s)

Both laws produce the following equation:

$$Q = I^2Rt \tag{2.3}$$

2.3 Resistance Spot Welding

There are several types of resistance welding. Resistance spot welding is known to be one of the categories of resistance welding. Resistance spot welding emerged in 1950s and it has become an important technology in joining metal sheets particularly in automotive field. Typical vehicle consist of about 3000-5000 spot welded joint. Parts that are spot welded are doors, cradle and etc. Resistance spot welding can be classified into three classes according to the thickness of the work pieces to be welded, large scale RSW (LSRSW), small scale RSW (SSRSW), and micro-RSW. For LSRSW, thickness of the metal sheets is between 0.41-1.57mm, which is normally used in automotive industry. Whereas, micro-RSW deals with the thickness thinner than 0.125mm and the thickness for SSRSW is between the other two classes, that can be found in medical devices, automotive electronics and telecommunication components (Salem, 2011).

The resistance spot welding is been favored as joining process because of the extremely low cost, which cost only less than one cent per weld. Furthermore, the high operation speed makes it suitable for automation in high production assembly line.

2.4 Welding Cycle

A welding cycle comprises of several discrete steps as shown in Fig. 2.1. The sequence is classified into four main steps, squeezing, welding, holding, and end. During the process of squeezing, the electrodes exert pressure on to the work pieces. Further on, the current is conveyed through the work pieces until a nugget is formed at the faying surface as shown in Fig. 2.2. Pressure is still applied to hold the work pieces when current is cut off until molten nugget cooled down into a solid nugget. At the final step, upper electrodes lifted up and leave the work pieces.

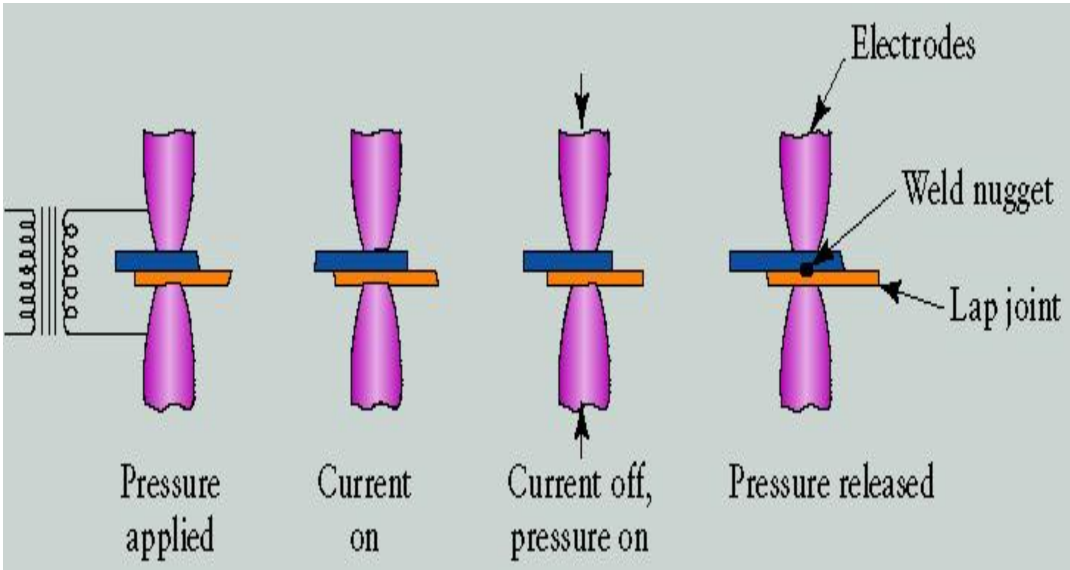

Figure 2.1Sequence in resistance spot welding operation.
(Source: (Kalpakjian, 2008))

A weld nugget can be formed when sufficient current and pressure is applied to generate enough heat to fuse both sheet metal and form a bonded between the sheet metals. Several studies have proved that the magnitude and duration of the current and the resistance of the work pieces determine the size of the nugget.

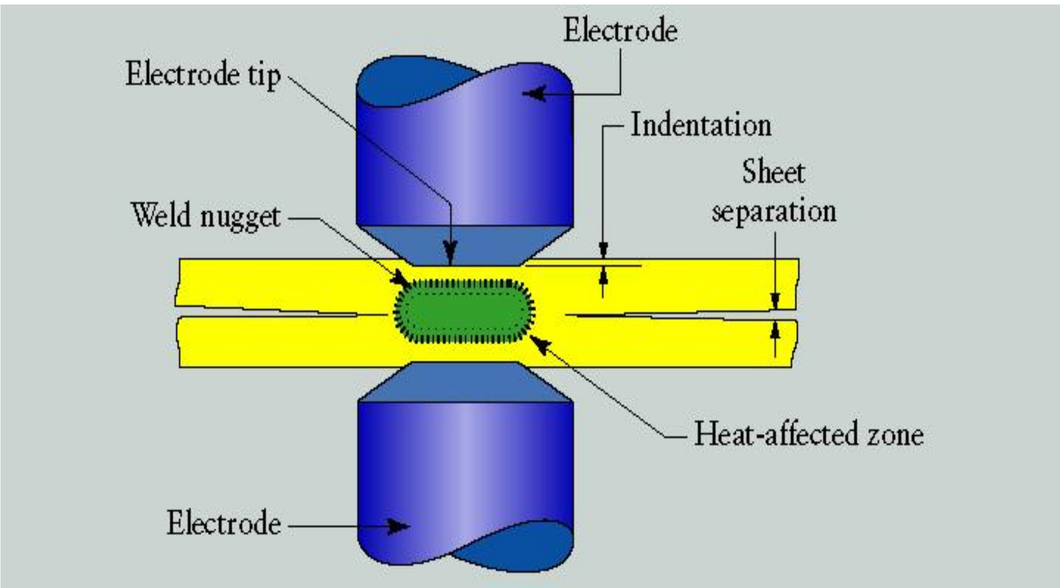

Figure 2.2 Cross-section view of a spot welding.
(Source: (Kalpakjian, 2008))

Three regions are identified after the welding process, the nugget, heat affected zone (HAZ) and base metal. Pouranvari, M. et al. (2008) determined the HAZ in galvanized steel sheet is wider than the stainless steel sheet due to the higher thermal conductivity. Besides, Mural, V and Akkus, A. (2004), have found out that there is heat unbalanced in the dissimilar joint weld nugget of stainless steel and galvanized steel sheet combination. Heat unbalanced cause the formation of asymmetrical weld nugget. One of the reasons which cause this to occur is due to the different properties between stainless steel and galvanized steel. The zinc layer is also said to be one of the reason of causing asymmetrical weld nugget.

2.4.1 Process Parameters

During the operation of spot welding, in order to obtain an optimum nugget size for certain thickness of work piece, the setting of parameter is the very important factor. The process parameters which have to be considered are as followed:

2.4.1.1 Electrode Force

According to the study made by Kaiser, J. G. et al. (1982), the contact resistance is highly affected by the factor of pressure particularly at the initial stages of heating cycle. Higher electrode force gives a higher pressure and leads to a reduction of contact resistance at the faying surface between electrode and sheet. Thus, would reduce the temperature at the contact surface, which might reduce the occurrence of expulsion. Therefore, electrode force adjudges the maximum nugget size without expulsion while the geometry of electrode is maintained constant. However, the larger which could cause an increasing of cost consumption. On top of that, a large electrode force might also damage the electrode and lead to excessive surface indentation (Kaiser, et al., 1982).

2.4.1.2 Squeeze Time

There is not much literature about the process parameter of squeeze time. It is the time where the electrodes clamps the work piece before the weld current is pass through. It is set to slow down the application of weld current until the electrode force has reached the desired level.

2.4.1.3 Weld Current

Many studies have been done on the parameter of weld current and determined that the amount of current affects the nugget forming and growth. Throughout the experiments which have been done by Pouranvari, M. et al. (2008) and Vural, M. et al. (2004), and Vural, M. (2006), they both concluded the increasing of weld current causes the increasing diameter of weld nugget. However, once the current reached the critical current value, the size/diameter of the weld nugget starts to decrease due to the excessive metal melting and splashing in the faying surface (Pouranvari, et al., 2008) (Vural, et al., 2006) (Vural & Akkus, 2004).