PROCEE PARAMETER RELATIONSHIP OF STAINLESS STEEL TO CARBON STEEL PIPES WELDING

YOONG SAI SIENG

B051210233

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This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Manufacturing Process) (Hons.)

by

YOONG SAI SIENG

B051210233

920907065817

FACULTY OF MANUFACTURING ENGINEERING

2016

DECLARATION

I hereby, declared this report entitled "Process Parameter Relationship of Stainless Steel to Carbon Steel Pipes Welding" is the results of my own research except as cited in references.

Signature : ……………………………………………

Author's Name : Yoong Sai Sieng

Date : 08 June 2016

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Manufacturing Process) (Hons.). The members of the supervisory committee are as follow:

……………………………….

(Principal Supervisor)

……………………………….

(Co-Supervisor)

ABSTRACT

Dissimilar pipe welding is widely used in industry especially power plant. The purpose of this method is to have the transition in mechanical properties to meet the requirement in different working condition. In addition, the economic purpose is another important factor because 304L austenitic stainless steel pipe is more expensive than BS1387 low carbon steel and material cost is limited for industry. The 304L austenitic stainless steel is used in the critical environment like high pressure and temperature region while BS1387 is used in low pressure and temperature region. In order to join both pipes, Gas Metal Arc Welding is performed and rotating jig is used to increase the consistency of the welding process. However, different physical properties of two different types of the steels cause them hard to join together. Hence, the objectives of this study are to study the effect of welding parameters that are current and welding speed to tensile and hardness properties of welded specimens, suggest optimized parameters for BS 1387 and SS 304L pipes welding and generate the regression models of tensile and hardness properties in BS1387 and SS304L pipes welding. Various currents and welding speeds are introduced and they are 175, 180, 185A and 60, 70, 80cm/min. Mechanical tests like tensile testing and microhardness testing are carried out after all the welding specimens were cut into desired shape by using Electro-Discharge Machine. The results revealed that welding speed is dominants the influence to the changes of the strength and hardness of the welded zone. Moreover, optimized set of parameters and regression models are suggested.

ABSTRAK

Kimpalan logam yang berbeza banyak digunakan dalam sektor industri terutamanya di dalam loji janakuasa. Tujuan untuk mengaplikasikan kaedah ini adalah untuk mendapatkan peralihan dalam sifat mekanik supaya dapat memenuhi keperluan dalam keadaan yang berbeza. Di samping itu, tujuan ekonomi juga adalah salah satu faktor yang penting sebab paip 304L keluli tahan karat austenit lebih mahal daripada paip BS1387 keluli karbon rendah dan kos bahan untul industri adalah terhad. Paip 304L keluli tahan karat austenit digunakan dalam persekitaran kritikal seperti kawasan yang mempunyai tekanan dan suhu yang tinggi manakala paip BS1387 keluli karbon rendah digunakan dalam kawasan yang mempunyai tekanan dan suhu yang rendah. Untuk mengabungkan dua jenis paip yang berlainan, Kimpalan Arka Logam Gas Lengai telah dijalankan dan jig yang berputar juga digunakan untuk menambahkan ketekalan proses kimpalan. Walau bagaimanapun, sifat-sifat fizikal yang berbeza untuk dua jenis keluli ini telah menyebabkan peningkatan kesusahan untuk mengabungkan dua jenis paip keluli ini. Oleh itu, matlamt untuk kajian ini adalah untuk mengajikan pengaruhan parameter seperti arus dan kelajuan kimpalan terhadap sifat ketegangan dan kekerasan untuk sampel-sampel dikimpal, mencadangkan jumlah optimum parameter untuk kimpalan paip BS1387 dan 304L, dan menghasilkan model-model regresi untuk sifat-sifat tegangan dan kekerasan dalam kimpalan paip BS1387 dan 304L. Beberapa arus dan kelajuan kimpalan telah diperkenalkan iaitu 175, 180, 185A dan 60, 70, 80cm/min. Ujian-ujian mekanikal seperti ujian tegangan dan ujian mikro-kekerasan telah dijalankan setelah sampel-sampel kimpalan telah dipotong kepada bentuk yang diiinginkan dengan menggunakan mesin Elektro-Discaj. Keputusan telah menunjukan kelajuan kimpalan adalah amat berpengaruh terhadap perubahan kekuatan dan kekerasan pada zon dikimpal. Selain itu, jumlah optimum untuk set parameter dan model-model regresi telah dicadangkan.

DEDICATION

To my beloved parents

Yoong Ee Sek

Tan Bee Hua

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

AISI	-	American Iron and Steel Institute
ANOVA	-	Analysis of Variance
ASTM	-	American Society for Testing and Materials
CO_2	-	Carbon Dioxide
DMW	-	Dissimilar Metal Welding
DOE	-	Design of Experiment
F	-	F Test (ANOVA)
FCAW	-	Flux Cored Arc Welding
GMAW	-	Gas Metal Arc Welding
GTAW	-	Gas Tungsten Arc Welding
HAZ	-	Heat Affected Zone
ISO	-	International Organization for Standardization
P	-	P-test (ANOVA)
UTS	-	Ultimate Tensile Strength

CHAPTER 1

INTRODUCTION

1.1 Background

Dissimilar Metal Welding is used in various applications in manufacturing sector like nuclear power plant, coal fired boilers, pharmaceutical, foods and beverages, and chemical industries. It is needed when transition in mechanical properties and performances in certain conditions are required. In power generation plant, the pipes that used to transfer high temperature steam are made of the austenitic stainless steels. However, at the region that has lower temperature and pressure, the application of austenitic stainless steels is unnecessary. Therefore, transition of the stainless steels to carbon steels is applied for economic purposes since the carbon steels can perform sufficiently at that environment (Kotecki and Lippold, 2005). In addition, the dissimilar thickness of pipes is used due to the different workload of the parts. Thinner part can be used in low working load while thicker part can be used in high working load (Hussein et al, 2016).

In this study, BS 1387 low carbon steel pipes and 304L austenitic stainless steel pipes are used. BS 1387 low carbon steel pipes are used for low pressure transportation while 304L stainless steels are widely used in varies applications. To join them, orbital pipe welding technique is needed. With the help of orbital pipe welding, human error is decreases and the productivity is increases. Besides, there are few methods to perform orbital pipe welding and Gas Metal Arc Welding (GMAW) is chosen. GMAW is consumable electrode arc welding process that equipped with continuous consumable solid wire electrode and shielding gas to perform welding process (Robert, 1999).

However, the different characteristics in between 304L stainless steel and low carbon steel influence the quality of the weld. The melting point and the heat conductivity of 304L stainless steel is lower than carbon steel and thermal stress is more contribute at the carbon steel (AISI, 1988). Therefore, the heat input needs to be controlled to prevent failure or low quality. To optimize the parameters, design of experiment method is used to list out all possible combinations of parameters and experiment is undergoes with the available combinations of parameters. With the tensile and hardness testing results, the optimized parameters can be found by using the design of experiment method.

1.2 Problem Statement

Dissimilar metal welding process is used to join the stainless steels to other materials like low carbon steels. This method is often used when transition in mechanical properties of two different materials are needed (Kotecki and Lippold, 2005). Moreover, the inherent cost can be reduced because the cost of the stainless steel is higher than low carbon steel (Westin and Garrett, 2010).

In this study, BS1387 carbon steel pipe and 304L stainless steel pipe are used. The filler material is 308L stainless steel. When welding is applied to the base metal, the hardness at heat affected zone (HAZ) is decreasing and the length of the HAZ is increasing. This is due to the changing at the microstructure of the HAZ (Ranjbarnodeh et al, 2012). Then, the melting point of the carbon steel is higher than the 304L stainless steel which means the stainless steel can be welded faster. In another perspective, the heat input to melt the carbon steel is higher than the heat input to melt the stainless steel. Moreover, the heat conductivity of the stainless steel is lower than the carbon steel and the heat expansion is higher than the carbon steel and this leads to the happen of distortion (AISI, 1988). In addition, the thickness of the stainless steel is thicker than the thickness of carbon steel and this has increases the difficulty of welding.

Therefore, optimization of the parameters is focused in this study rather than study effect of repetitive repair welding on the weld part. The optimized parameters can be used to study the effect of repetitive repair welding on the weld part and suggest the optimum number of repair welding to BS1387 low carbon steel pipe and 304L austenitic stainless steel pipe.

1.3 Objectives of Study

Objectives of the study are:

i. To study the effect of welding parameters that are voltage, current and welding feed speed to tensile and hardness properties of welded specimens.
ii. To suggest optimized parameters for BS1387 and 304L pipes welding.
iii. To generate the regression models of tensile and hardness properties in BS1387 and 304L pipes welding.

1.4 Scope of Study

In this study, two types of steel pipes were prepared, 304L austenitic stainless steel and low carbon steel. The pipe specimens of stainless steel had outer diameter 40mm, length 100mm and thickness 5mm. On the other hand, the pipe specimens of low carbon steel had outer diameter 40mm, length 100mm and thickness 4mm. GMAW was the heat source to perform orbital pipe welding. The type of shielding gas was 30% Carbon Dioxide and 70% Argon, and wire electrode used was AWS ER 308L with diameter 1.2mm. The parameters that have been studied were current and welding speed. The levels of the current were 175, 180 and 185A while levels of the welding speed were 60, 70 and 80cm/min. Full factorial design technique was used to list out all the possible parameters combinations.

During the welding process, rotational jig that available in the lab was used to hold the pipe and rotate the pipe. Torch was fixed by the holder located at the rotational jig and rotational speed which acted as welding speed. In addition, tack weld was performed before the welding process to temporary hold the pipe at correct alignment and distance. After the welding process, tensile test and micro-hardness test were carried out to get the data such as ultimate tensile strength (UTS), elongation and hardness level of the base metals and weld part. Micro-hardness testing machine and universal tensile machine that available in the laboratory were used to carry out these testing.

1.5 Significance of Study

Dissimilar welding process is important in industries such as power generation plant that contain high temperature steam. Dissimilar welding process is needed due to the transition of mechanical properties and cost effectiveness (Kotecki and Lippold, 2005). Unfortunately, the different characteristics of the materials are increasing the possibility of failure to joint them. Therefore, this study is focus on the optimization of the parameters used to weld the stainless steel to carbon steel pipes. With the optimized parameters, the cost used to join stainless steel to carbon steel pipes is decreases and the properties at the weld part are sustainable at the service environment.

Besides, the microstructure and properties of the weld part and HAZ are changing and weakening when the number of repair welding is increases. With the increasing of number of repair welding, the properties of weld part and HAZ will fail to service at the particular environment, temperature and pressure. Therefore, the optimized parameters that obtained in this study can be used to further study on the optimum number of repetitive repair welding can be done to this dissimilar pipe welding.

1.6 Activity Planning

Activity planning of this study is outlined in the Gantt Charts as in Appendix A and B. The Gantt Charts are prepared for both PSM 1 and PSM 2.

CHAPTER 2

LITERATURE REVIEW

This chapter focuses on the review of the literature from the journal, article, book and other resources. Generally, this chapter has been divided into four sections, materials, welding methods， parameters of welding process and testing methods.

2.1 Carbon Steel

Carbon steel is most widely used steel in the world. Composition of the carbon will affects the properties of the carbon steel in hardness, tensile strength, ductility and others. Carbon steel can be divided into low carbon steel, medium carbon steel and high carbon steel. The amount of the carbon contain is the way to differentiates them into the three groups (Seblin et al, 2005). Generally, carbon steel is iron-based alloy that contains less than 2% composition of carbon.

Other than carbon, elements like silicon, aluminium, manganese and cerium are added to improve the properties of the carbon steel. In industry sector, carbon steel is famous materials to use due to the mechanical properties, ease of fabrication and availability. For sure, the most important factor is the cost. It is not only use in structural fabrication, it also widely used in water and steam containing system. Moreover, carbon steel is used to manufacture boilers, pressure vessels, tubes, pipes and heat exchangers (Handbook, 2007). Not only for industry purpose, carbon steel is used to produce car bodies, kitchen appliances and cans (Seblin et al., 2005).

2.1.1 Low Carbon Steel

Carbon steel with below 0.25% of carbon is categories as low carbon steel (Seblin et al., 2005). The microstructure of the low carbon steel is builds up mainly by pearlite and ferrite phases. Normally, low carbon steel is directly goes through hot forming or cool forming process due to its workability and ease of fabricate. The ease of fabricate characteristic of low carbon steel is encourages manufacturers to form it into certain shapes through few methods like pouring, moulding and pressing. Low carbon steel can changes its formation easily through the manufacturing process.

Therefore, it is uses to produce machine parts, chains, rivets, nails, wires and pipes (Litherland, 1999). Although the strength of the low carbon steel is not outstanding due to the composition of carbon is low but it has better formability that other types of steel would not have. Another advantages that low carbon steel had is the weld ability, this is due to the low content of carbon composition. The hardness of the steel increase with the amount of carbon content in the steel, but the probability of cracks will occurs is increasing (Weiss, 2013).

2.1.2 Medium Carbon Steel

The carbon content of medium carbon steel is in between 0.25% to 0.70%. It is needs to undergo heat treatment to improve the machinability (Seblin et al., 2005). Medium carbon steel is alloying with chromium, nicker and molybdenum to improve the tensile strength, wear resistance and toughness. With these properties, medium carbon steel is widely uses in producing gears, axles, studs and other machine parts that need high strength and high toughness (Misumi, 2014).

2.1.3 High Carbon Steel

High carbon steel is steel with carbon content in between 0.70% to 1.05%. To obtain high shear and wear resistance, fully heat-treatment is applies to the high carbon steel. Therefore, it can have high hardness thus little deformation occurs when subjected to forces. At high hardness, high carbon steel has more brittle behaviour. If toughness is required, the adjustment in between hardness and toughness needs to be considered (Seblin et al., 2005). With the high hardness, high strength and good wear resistance, high carbon steel is manufactures to knife, saw blade, spring, gear wheel, chain and others wear parts (Metals, 2012).

Moreover, different carbon content in the steel is determines the mechanical properties, brittle or ductile behaviour of the steel and this is depends on the application. It is influences by the microstructure of the steel. For carbon content lower than 0.2%, 75% of the microstructure of carbon steel is made up of pro-eutectoid ferrite phase and the other 25% is pearlite phase. As the rises of the carbon content, the amount of pearlite is increases. At 0.8% of carbon content, the fully pearlite structure is obtained. Beyond that carbon content, microstructure of the carbon steel is consists of pro-eutectoid cementite and pearlite. The increase of the cementite content is increases the hardness but decreases the ductility. Therefore, high carbon steel is more brittle than low carbon steel and medium carbon steel (Seblin et al., 2005).

2.1.4 BS1387 Low Carbon Steel

BS 1387 low carbon steel is standardized according to British Standard BS 1387:1985. Typically, it is used in scaffolding and low pressure liquids flow such as water, gas, oil and machinery. It is categories to three degrees which are light, medium and heavy. It is differentiates by the colours, brown, red and blue.