STATISTICAL ANALYSIS OF REPETITIVE REPAIR WELDING USING GMAW ON STAINLESS STEEL JOINT

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

by

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I hereby, declared this report entitled “Statistical Analysis of Repetitive Repair Welding Using GMAW on Stainless Steel Joint” is the result of my own research except as cited in reference.

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APPROVAL

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

……………………………………….

(Profesor Madya Dr. Nur Izan Syahriah Binti Hussein CEng)

ABSTRAK

Kajian ini terutamanya mengenai kimpalan pembaikan berulang pada keluli tahan karat yang sama menggunakan GMAW. Bahan yang dipilih ialah AISI304 dan proses kimpalan yang digunakan adalah GMAW. AISI 304 digunakan secara meluas dalam persekitaran kerja suhu tinggi, jadi mereka akan menghadapi banyak kerosakan dan kegagalan. Pembaikan kimpalan adalah salah satu proses penyelenggaraan penting. Proses pembaikan kimpalan dapat mengembalikan fungsi asal keluli tahan karat AISI304 jika kegagalan kimpalan berlaku akibat penurunan atau kecacatan semasa tahap fabrikasi. Oleh itu, proses ini lebih mudah daripada menggantikan atau membeli bahagian atau struktur baru. Walau bagaimanapun, pembaikan kimpalan berulang akan menghasilkan input haba yang tinggi kepada logam kimpalan dan mengubah sifat mikrostruktur dan mekanikal. Kajian ini juga mengkaji tentang kesan pembaikan kimpalan berulang pada keluli tahan karat AISI 304 kepada perubahan mikrostruktural dan sifat mekanik pengagregatan. Kombinasi input haba yang rendah yang berlaku semasa proses kimpalan pembaikan menghasilkan kekuatan yang agak tinggi dan sebaliknya. Seterusnya, hasil ujian menunjukkan bahawa struktur dendritik telah terbentuk semasa kimpalan, yang kebanyakannya mengandungi struktur delta ferit dan austenit. Logam asas pada awalnya mempunyai struktur mikro yang terdiri daripada matriks austenit dan jalur delta-ferit. Walau bagaimanapun, mikrostruktur berubah sebagai input haba yang diinduksi pada bahagian yang dikimpal yang menyebabkan delta ferrite mencairkan sebahagiannya dalam HAZ yang menghasilkan nilai mikrohardness yang agak rendah berbanding logam kimpalan.

ABSTRACT

This study is mainly about repetitive repair welding on similar stainless steel joint using GMAW. The material chosen is AISI304 and the welding process used is GMAW. AISI 304 is being used widely in high temperature working environment so they will face a lot of damage and failure. Repair welding is one of the important maintenance processes. Repair welding process able to restore original function of a part if weld failure happened due to service drop or defect during fabrication stage. Thus, this process is more convenient rather than replacing or buy new parts or structure. However, repetitive repair welding will produce high heat input to the weld metal and change the microstructural and mechanical properties. This study also reviewed about the effect of repetitive repair welding on AISI 304 stainless steel to the microstructural changes and mechanical properties of the weld metal. The planning matrix of parameters used was designed using Taguchi Method. After finished the analysis of the results using Analysis of Variance method (ANOVA), the optimum parameters for first repair are proposed and the modeling values are gained as reference for the next repair weld process. The low heat input combinations that occur during the repair welding process produce relatively high strength and vice versa. Subsequently, test results show that dendritic structures have been formed during welding, most of which consist of ferrite and austenite delta structures. The basic metals initially had a micro structure consisting of austenitic matrices and delta-ferrite bands. However, the microstructure changes as an induced heat input on the welded part which causes the ferrite delta to partially melt in HAZ which produces relatively low microhardness values over the weld metal.

DEDICATION

Only to my beloved father Akasak bin Manap,
my mother Saimah binti Kumik.
Also not to forget my dear siblings
Norlela, Norlizam, Norhalim, Norbaizurah and Norizwan
for helping me all the time.
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LIST OF ABBREVIATIONS

GMAW	-	Gas Metal Arc Welding
ASS	-	Austenitic Stainless Steel
SMAW	-	Shielded Metal Arc Welding
GTAW	-	Gas Tungsten Arc Welding
SAW	-	Submerged Arc Welding
FCAW	-	Flux Cored Arc Welding
MIG	-	Metal Inert Gas
RCP	-	Reactor Coolant Pump
GMAW-S	-	GMAW (Short-circuit Transfer)
GMAW-P	-	GMAW (Pulsed-arc Transfer)
DCEP	-	Direct Current Electrode Positive
DC	-	Direct Current
AC	-	Alternating Current
YS	-	Yield Strength
UTS	-	Ultimate Tensile Strength
AW	-	As Weld
HAZ	-	Heat Affected Zone
DOE	-	Design of Experiment
MW	-	Manufacturing Weld
WEDM	-	Wire Electrical Discharged Machining
ANOVA	-	Analysis of Variances
BM	-	Base Metal
WM	-	Weld Metal

LIST OF SYMBOLS

mm	-	millimeter
A	-	current
V	-	voltage
mm/min	-	millimeter per minute
Ar	-	Argon
CO_2	-	Carbon Dioxide
O_2	-	Oxygen
He	-	Helium
gf	-	gram-force
s	-	second
μm	-	micrometer
C	-	Carbon
Cr	-	Chromium
Ni	-	Nickel
Si	-	Silicon
P	-	Phosphorus
S	-	Sulfur
N	-	Nitrogen
Mo	-	Molybdenum
Cu	-	Copper
Mn	-	Manganese
MPa	-	mega pascal
kN	-	kilo newton

CHAPTER 1

INTRODUCTION

In this chapter, the topic discussed is the background of study that consist some of general information about the study of project that combined with some facts from the journal. In this chapter also included problem statement of the project, objectives to be achieved, scope that covers to achieve the objectives, significant of studies, and organization of thesis.

1.1 Background of Study

Gas Metal Arc Welding (GMAW) is a welding process which an electric arc forms between a consumable wire electrode and the work piece metal, which will heats the work piece metal causing them to melt and joint together. Both the arc and weld pool are protected from the atmospheric contamination by an inert gas as a shield which is sent through a nozzle that is concentric with the welding wire guide tube. GMAW has been commercially available around 60 years. It is commonly used as industrial welding process. The main factors of this happening are because of its versatility, speed and the ease of adapting the process even to robotic automation.

The definition of orbital welding is the circular movement of welding tool or welding torch around the workpiece to be welded. This orbital welding process mainly involve in industries such as pharmaceutical, aircraft, food and beverage, chemical, fossil and nuclear power plant. It is often used to join tubes or pipes over the other types of joining methods. Whenever advance quality weld are required, orbital welding is the most chosen process for the joining of tubes. This is not only because it provides best weld quality, it also can perform easily and smoothly in a cramped working environment (Polysoude, 2009).

The demand on stainless steel usage in industry increase drastically as a result of rapid growth, combined with the limitations in production routes and dynamic raw materials price of major alloying addition such as nickel, molybdenum, and chromium have stimulated engineering companies and fabricators to create alternative grades to the commercial austenitic stainless steel with attractive corrosion and mechanical properties as well as stable price. Austenitic stainless steel (ASS) has good trade carrying into action in corrosive working environment. This type of stainless steel is suitable in either conducive or high temperature service environment. Other than that, they also convey good mechanical properties, especially toughness and ductility, so that it shows exceptional elongation during tensile testing.

Repair welding is often carried out in steel structural components. The main intention of repair welding is by providing cure for existing welding defects during initial stages or weld deterioration during their services that can increase the service lives or performance of components. Repair welding is a better choice compared to replacing the parts because it is more economical, faster and reliable method to make a part come back to its services when failure of the parts is identified. Wrong processes and poor handiwork such as excess or incomplete weld penetration at fabrication stage can cause failure to the weld. Besides that, inappropriate selection of filler metal used in welding operation also can cause failure to the weld. Another cause that leads to the failure of weld is stagnation during services, where the working environment is corrosive or emphasizes by stress corrosion (Cary, 2002).

1.2 Problem Statement

Welded parts break and destroy consistently mostly because of corrosive environment and high temperature services. It might be difficult to get another part precisely like the one that broke or destroyed. This is especially valid for more established modern hardware, development machinery, agricultural machinery, machine instruments parts and even automotive parts. The fixed parts might be more functional than the original parts since they can fortify the shortcomings of the original parts were remedied. Usually, it is more conservative to weld repair parts since the delaying in acquiring the new parts could be over the top and the expense of new parts would increase over the expense of fixing the broken parts (Total Materia, 2004).

The Welding Institute (TWI) conducted an industry survey on 'repair rates' in 2011 and came up with the average repair rates for different welded products/parts based on typically used material grades as shown in Table 1.1 and Figure 1.1.

Table 1.1 : Average repair rates for different welded products and materials (The Welding Institute, 2012)

Type of product	**Average repair rate, any material grades, %**	**Average repair rate per material grade, %**					
		Mild steel	**Stainless steel**	**Low-alloy steel**	**Ni-alloy**	**Low-temperature steel (eg: Ni steel)**	**High strength steel**
All products	-	2.0	2.2	3.1	3.4	2.2	-
Offshore structures (3)	2.0	2.1(1)	1.1	-	2.0(1)	2.2	-
Other welded structures (3)	1.0	1.5(1)	0.7	-	-	-	-
Piping systems (4)	3.0	1.7	3.5	4.2(1)	-	-	-
Pressure vessels(4)	2.0	2.8	1.1	0.5(2)	-	1.7	-

Offshore pipelines (4)	2.0	0.9	7.5	-	-	1.8	-
Onshore pipelines (4)	3.0	2.5(1)	-	2-5(2)	-	2-5(1)	-
Cryogenic storage tanks (4)	0.5(2)	-	0.5(2)	-	-	-	-
Hydroelectric turbines (3)	1-2(2)	1-2(2)	-	-	-	-	-

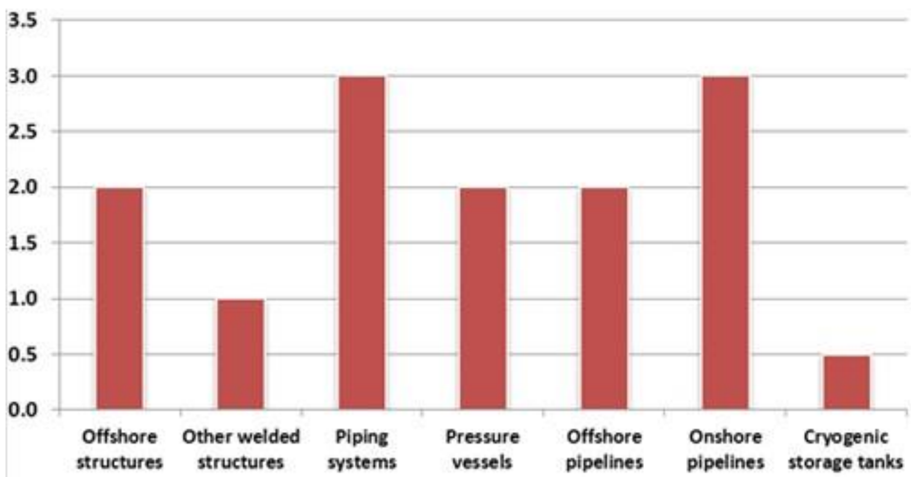

Figure 1.1 : Average repair rates for different types of products/parts (The Welding Institute, 2012).

Figure 1.1 shows average repair rates for the oil and gas and power sectors range from 1-3%. The rates peak up to 25% in specific locations were recorded and abnormally values up to 55% were logged. The peak repair rates are commonly observed in specific locations within welded products such as roots, fillet welds, and areas with limited access to it. The skill of welders, location or accessibility of welds, and poor fit-up prior to welding are the most crucial factors identified to affect the repair rates.

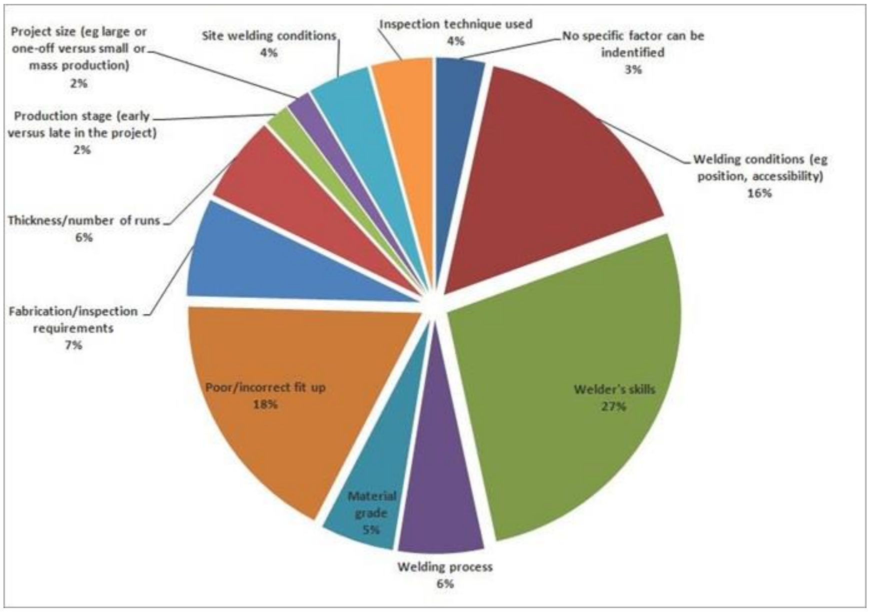

Figure 1.2 : Distribution of factors affecting repair rates in weld (The Welding Institute, 2012).

The distributions of factors affecting repair rates in welds are shown in Figure 1.2. The repair rates were calculated with different technique. The offshore parts and other welded parts data given as fraction of the length of repaired weld versus total weld length. Meanwhile, for piping systems, onshore and offshore pipelines, data given as the number of repaired welds versus total number of welds. As for pressure vessels, data given as number of repaired welds versus total number of welds (The Welding Institute, 2012).

As a result, repair welding is often required in industry to extend the service life or to increase performance of the parts or components by giving remedy for existence of welding damages during primary stage or weld deterioration during their services (Zeinoddini et al., 2013). Besides, performing repair welding is low-cost rather than purchasing new parts or components which will increase the cost. Furthermore, repair welding is comparatively cost-effective than replacing the parts because delay time during waiting of the replacement parts might bring irretrievable lost to a company (Total Materia, 2004). In conclusion, repair welding is significant for reduce cost, minimize break down time and extending the service life of a part or component.

The effect of repair welding on AISI 304 based on tensile strength, microhardness value, and microstructural change will be highlighted in this study. Thus, the optimum number of repetition repair weld can be anticipated from this study.

1.3 Objectives

The objectives for this study are:

i. To design the experiment using Taguchi Method.
ii. To investigate the effect of repetitive repair welding using GMAW on mechanical properties and microstructural change of AISI 304 austenitic stainless steel.
iii. To propose the optimum parameters for first repair weld process.

1.4 Scopes

In this study, AISI 304 will be used as specimens with size of 60mm in diameter, 100mm for length and 4mm for thickness. The heat source chosen is orbital gas metal arc welding (GMAW) by using TransSynergic 4000. For GMAW, binary blend shielding gas consist of 70% argon, 30% carbon dioxide and 1.2 mm diameter of AWS E308L-16 wire electrode are used.

Other than that, optimized parameters acquired from previous study are applied in this study, which are arc current is 133A, arc voltage is 21V, and welding speed is 25mm/min (Nurul, 2014). The planning matrix of experiment is design using Taguchi Method to get the parameters used for repair welding. After that, all specimens will undergo destructive testing such as tensile testing and microhardness testing.

1.5 Importance of Study

Repair welding can be completed as a coherent method that guaranteed the production of a usable and safe component, or it can be approached haphazardly (Salami, 2014). This process gives benefit to the company in wide fields of application such as oil and gas, pharmaceutical and food industry. In addition, repair welding can restore a parts original service life if weld failure occurred because of service deterioration or damage during manufacturing stage. The study on repair welding will help to solve problems quickly and efficiently. Repair welding help to increase the performance of the parts and help to extend the service life of parts or components. It is also a cost-effective method to reduce cost and reduce waiting time of new parts and components.

1.6 Organization of the Report

This research consists of 4 main chapters which are:

Chapter 1: Introduction

This chapter is mainly described about the background of topic that has been chosen. Besides that, the problem statement and objectives to be achieved in this study also listed followed by the scope of research. The important of study and organization of the report also listed.

Chapter 2 : Literature Review

The content related to orbital GMAW and repair welding are covered in this chapter. Additionally, it covered about the joining process, heat source and material used.