# EFFECT OF REPETITIVE REWORK ON DISSIMILAR AUSTENITIC STAINLESS STEEL PIPES BY USING GMAW ORBITAL WELDING

TAN HUAY KEAN
B051110082

UNIVERSITI TEKNIKAL MALAYSIA MELAKA
2015

B051110082 BACHELOR OF MANUFACTURING ENGINEERING (MANUFACTURING PROCESS) (HONS.) 2015 UTeM

# UNIVERSITI TEKNIKAL MALAYSIA MELAKA

# EFFECT OF REPETITIVE REWORK ON DISSIMILAR AUSTENITIC STAINLESS STEEL PIPES BY USING GMAW ORBITAL WELDING

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

**TAN HUAY KEAN**
**B051110082**
**910912-08-5768**

FACULTY OF MANUFACTURING ENGINEERING
2015

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

**BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA**

TAJUK: **Effect of Repetitive Rework on Dissimilar Austenitic Stainless Pipes by Using GMAW Orbital Welding**

SESI PENGAJIAN: **2014/15 Semester 2**

Saya **TAN HUAY KEAN**

mengaku membenarkan Laporan PSM ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Laporan PSM adalah hak milik Universiti Teknikal Malaysia Melaka dan penulis.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
3. Perpustakaan dibenarkan membuat salinan laporan PSM ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (✓)

| | | |
|---|---|---|
| ☐ | SULIT | (Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia sebagaimana yang termaktub dalam AKTA RAHSIA RASMI 1972) |
| ☐ | TERHAD | (Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan) |
| ☐ | TIDAK TERHAD | |

Disahkan oleh:

_________________________ _________________________

Alamat Tetap:

NO. 12, Jalan Muhibah 5,

Kuala Gula 34350

Kuala Kurau, Perak

Cop Rasmi:

Tarikh: 30 June 2015

Tarikh: 30 June 2015

** Jika Laporan PSM ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan PSM ini perlu dikelaskan sebagai SULIT atau TERHAD.

# DECLARATION

I hereby, declared this report entitled "Effect of Repetitive Rework on Dissimilar Austenitic Stainless Steel Pipes by Using GMAW Orbital Welding" is the results of my own research except as cited in references.

| | | |
|---|---|---|
| Signature | : | …………………………………………. |
| Author's Name | : | Tan Huay Kean |
| Date | : | 30 June 2015 |

# 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)

# ABSTRAK

Kimpalan logam yang berbeza banyak digunakan untuk memenuhi keperluan peralihan dalam sifat mekanik ataupun perbezaan dalam keadaan bekerja. Walaupun kedua-dua AISI 304 dan AISI 316L berada dalam kategori keluli tahan karat austenit tetapi masing-masing mengandungi komposisi utama yang sedikit berbeza. Oleh itu, mereka digunakan di keadaan bekerja yang berbeza. Sebagai contohnya, AISI 304 digunakan untuk aplikasi suhu tinggi, manakala AISI 316L lebih sesuai untuk aplikasi suhu rendah. Pembaikan kimpalan merupakan satu kaedah yang biasanya digunakan untuk komponen keluli buatan. Jika kegagalan kimpalan dijumpai, pembaikan kimpalan boleh mengembalikan fungsi komponen itu semula. Oleh itu, objektif untuk kajian ini adalah mencirikan sifat-sifat paip AISI 304 dan AISI 316L sebelum proses kimpalan, menyiasat kesan pembaikan kimpalan yang berulang-ulang pada paip keluli tahan karat austenit dari aspek mikro kekerasan, kekuatan tegangan, mikrostruktur dan kualiti. Kemudian, jumlah optimum untuk mengulangi proses pembaikan kimpalan dicadangkan. 133 A arus arka, 21 V voltan arka dan 25 mm/min kelajuan kimpalan merupakan parameter optimum yang akan digunakan dalam kajian ini. Seterusnya, setiap kimpalan paip yang berbeza bahan akan tertakluk kepada dua jenis ujian iaitu ujian tanpa musnah dan ujian mekanikal. Ujian penusukan cecair digunakan untuk memeriksa permukaan kimpalan sama ada retakan ataupun kecacatan kimpalan yang lain dapat dijumpai. Kemudian, mikroskop optik digunakan untuk pemerhatian makrostuktur dan mikrostruktur. Selepas itu, ujian mikro kekerasan dan ujian kekuatan tegangan merupakan ujian mekanikal yang akan dijalankan. Akhirnya, hasil pengujian menunjukkan kualiti kimpalan logam dan transformasi mikrostruktur akan mempengaruhi sifat mekanikal.

# ABSTRACT

Dissimilar metal welding is widely applied to meets the requirements of transition in mechanical properties and/or difference in working conditions. Even though AISI 304 and AISI 316L are both belong to austenitic stainless steels, but their nominal composition is slightly different. Thus, they are applied in different working environment, where AISI 316L has contact with working media, but AISI 304 does not have. On the other hand, repair welding is a method that usually employed in steel-made structural components. This method is able to return a part or component back to its normal service life if weld failures happened due to service deterioration or defects during fabrication stage. However, repetitive heat input due to repair welding will cause changes in welded structure. Therefore, the objectives of this study are to characterize the properties of as-received AISI 304 and AISI 316L austenitic stainless steel pipes, investigate the effect of repetitive repair welding on quality, microstructure, microhardness and tensile properties of welded dissimilar stainless steel pipes and suggest an optimum number of repetitions for the dissimilar stainless steel pipes repair welding process. Throughout this study, optimized parameters where arc current 133 A, arc voltage 21 V and welding speed 25 mm/min that obtained from previous researchers was used to perform the repair welding. After that, every welded dissimilar pipe was subjected to non-destructive testing and mechanical testing. In prior to mechanical testing, quality of welded pipe was checked by using liquid dye penetrant testing. Then, optical microscope was applied for macrostructural and microstructural examination. After that, microhardness testing and tensile testing were carried out by using Vickers microhardness tester and tensile tester respectively. The results revealed that quality of welding and the microstructure transformation had effect on mechanical properties of dissimilar metal weld joint.

# DEDICATION

To my beloved parents,

*Tan Lay San*

*Lim Bee Hua*

# ACKNOWLEDGEMENT

I would like to express my great appreciation to my supervisor Dr. Nur Izan Syahriah binti Hussein for giving me continuous guidance and advice despite her hectic schedules. I believed that my final year project could not be accomplished successfully without her help. She always willing to spend her time to meet me and give me consultations whenever I have doubts in my project work. In addition, I also wish to thanks my family members and friends for giving me encouragements and supports during the period in preparing my report. Their concern and support truly motivated me in all the hard times.

# TABLE OF CONTENT

**APPENDICES**

# LIST OF TABLES

# LIST OF FIGURES

# LIST OF EQUATIONS

# LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

| | | |
|---|---|---|
| AC | - | Alternating Current |
| AISI | - | American Iron and Steel Institute |
| ASTM | - | American Society for Testing and Materials |
| AWS | - | American Welding Society |
| ASME | - | American Society of Mechanical Engineers |
| DC | - | Direct Current |
| DMW | - | Dissimilar Metal Welding |
| FCAW | - | Flux Cored Arc Welding |
| GMAW | - | Gas Metal Arc Welding |
| GTAW | - | Gas Tungsten Arc Welding |
| HAZ | - | Heat Affected Zone |
| SCC | - | Stress Corrosion Cracking |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background Study

Orbital welding is the most applicable joining process in industry whenever high quality of welding results is desired. It is mainly involved in industries such as aircraft, pharmaceutical, food, diary and beverage, chemical, fossil and nuclear power plants. Indeed, the name orbital welding is defined based on the circular movement of welding tool or welding torch around the workpiece to be welded. Orbital welding always has priority for joining tubes or pipes over the other types of joining methods. This is because it not only provides sophisticated weld quality; meanwhile, it can also perform easily and smoothly in the congested working environment (Polysoude, 2009).

Dissimilar metal welding (DMW) is usually established by joining stainless steel to other materials, for instance dissimilar metal joints between AISI 304 and AISI 316L. Although these two materials are both belong to type of austenitic stainless steel, but they are slight different in their nominal composition. Austenitic stainless steels have good performance in corrosive working environment. This type of stainless steel is applicable in either conducive or elevated temperature service environment. Besides that, they have also good mechanical properties particularly ductility and toughness, so that it shows remarkable elongation during tensile testing. Indeed, practice of DMW with formation of dissimilar metal joint allows the transition in mechanical properties or in service conditions as required in certain applications (Lippold and Kotecki, 2005).

Repair welding is a favorable choice rather than replacement parts. This is because it is more economical, faster and reliable approach to bring a part back to service when failure of the part is encountered. The failure of the weld may be due to the incorrect processes or poor workmanship, for example incomplete weld penetration in the early of fabrication stages. Besides that, there is also a possibility where inappropriate selection of filler metal that used for welding operation. Another cause that leads to failure of weld is deterioration during service, where the working environment is corrosive or accentuated by stress corrosion (Cary, 2002).

## 1.2 Problem Statement

Dissimilar metal welding has gained its popularity and well-established in catering the requirement of transition in mechanical properties and/or variation of service environments (Lippold and Kotecki, 2005). This method is especially popular in pharmaceutical industry, in which the fabrication of pressure vessel involved joining of two different types of stainless steel material. Most of the time austenitic type is the primary choice for pharmaceutical equipment due to their remarkable properties, particularly corrosion resistance and weldability. For instance, vessels made from AISI 304 and AISI 316L are joined together but they work in different circumstances, where vessels AISI 316L have contact with working media, yet AISI 304 does not (SK Group, 2012).

Since pharmaceutical equipment always subjected to high temperature and pressure, they are more susceptible to premature failure after a certain service period and it becomes more critical when there is involvement of dissimilar metal weld joints. This is because dissimilar metal weld joints have higher tendency encountered to material degradation such as thermal aging. Besides that, dissimilar metal weld joint has other problems such as carbon migration from high alloy to low alloy side or formation of brittle intermetallic compound (Mvola et al., 2014). In addition, any cracking or other stress concentrators found in the weld joint also greatly affected the structural integrity of the part. Consequently, the lifespan of the part is shortened and it can bring severe disaster due to the unexpected failure (Kyung et al., 2012).

As a result, repair welding is often desired in industry to prolong the service lives or enhance performance of the components by providing remedy for presence of welding defects during initial stages or weld deterioration during their service (Zeinoddini et al., 2013). Besides that, it is more economical to perform repair welding rather than purchase a new component as the purchasing cost is certainly higher. Moreover, repair welding is comparatively cost-effective than make replacement of the part. This is because delay time during waiting the replaced part might cause an irreparable lost to a company (Total Materia, 2004). Moreover, repair welding is undeniably useful in giving indication for usability and safety of a component or part (Gupte, n.d.). Overall, repair welding is important in saving cost, minimizing break down time and extending service life of a part (American Welding Society, 2014).

Nevertheless, limited research has been done on the repair welding that involved dissimilar metals. Majority of the researcher are focused on the repair welding of single metal type. Therefore, the effect of repair welding on AISI 304 and AISI 316L will be emphasized in this study. Based on the changes of mechanical properties and microstructural transformation after each weld repair, the useful service life of this dissimilar metal joint can be anticipated.

## 1.3 Objectives

The objectives of this study are:

i. To characterize the properties of as-received AISI 304 and AISI 316L
ii. To investigate the effect of repetitive repair welding on quality, microstructure, microhardness and tensile properties of welded dissimilar stainless steel pipes
iii. To suggest an optimum number of repetition for the dissimilar stainless steel pipes repair welding process

## 1.4 Scope of Study

In this study, two types of austenitic steels pipe are prepared, one is AISI 304 and another one is AISI 316L. The specimens are all in diameter 60mm, length 100 mm and thickness 4 mm. Orbital gas metal arc welding (GMAW) is the selected process to perform repair welding on specimens by using TransSynergic 4000. For GMAW, binary blend shielding gas of 70% argon/30% carbon dioxide and 1.2 mm diameter of AWS E308L-16 wire electrode are used. In additional, optimized parameters obtained from the previous research are applied in this study, where arc voltage is 21 V, arc current is 133 A and welding speed is 25 mm/min (Nurul, 2014).

It is essentially to remove the weld bead in prior to every repair welding. Then, all welded specimens are subjected to both non-destructive testing and destructive testing. Dye penetrant testing is the non-destructive testing method that applied to inspect surface defects or surface discontinuities by using SPOTCHECK dye penetrant. Then, Zeiss optical microscope with image analysing software is used to observe the fusion zone and HAZs of welded joints between dissimilar metals after repetitive repair.

After all, destructive testing such as microhardness testing and tensile testing are carried out by using HM-221 micro-Vicker hardness tester and Shimadzu AG1 tensile tester respectively.

## 1.5 Project Outline

Basically, this full report consisted of five chapters.

Chapter 1: Introduction
Background study is illustrated based on the research title. Besides that, the problems statements and objectives to be achieved in this study are also listed. Then, it is followed by scope of study and project outlines also included in this chapter.

Chapter 2: Literature Review
The issues related to orbital GMAW of dissimilar metals and repair welding are covered here. In additional, types of stainless steel, in particular austenitic stainless steels and their applications are described.

Chapter 3: Methodology
This chapter included preparation of test specimen and experimental set up. Testing procedures and instrumentations that are required to accomplish the testing also described here.

Chapter 4: Results and Discussion
The images captured for quality inspection and microstructure at different welding zones were displayed. Then, results obtained from microhardness testing and tensile testing were tabulated. After that, the results were analyzed and correlation between quality, microstructural transformations and mechanical properties was made.

Chapter 5: Conclusions and Recommendations
Several conclusions were drawn from the experimental study that have already done and it is actually summarization of whole project. Then, few recommendations were outlined for future work and also for improvement of current study.