EFFECT OF DIRECT METAL DEPOSITION OF STAINLESS STEEL 308 LSi WIRE ON STAINLESS STEEL 304 BASE PLATE

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2017

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

by

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FACULTY OF MANUFACTURING ENGINEERING

2017

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

Tajuk: **EFFECT OF DIRECT METAL DEPOSITION OF STAINLESS STEEL 308 LSi WIRE ON STAINLESS STEEL 304 BASE PLATE**

Sesi Pengajian: **2016/2017 Semester 2**

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I hereby, declared this report entitled "Effect Of Direct Metal Deposition Of Stainless Steel 308 LSi Wire On Stainless Steel 304 Base Plate" is the result of my own research except as cited in references.

Signature	: ....
Author's Name	: MOHD SYAZWAN BIN MOHD NIZAM
Date	: 19 June 2017

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Manufacturing Process) (Hons).
The member of the supervisory committee are as follow:

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(PROF MADYA DR. NUR IZAN SYAHRIAH BINTI HUSSEIN)

……………………….................

(MOHAMAD NIZAM BIN AYOF)

ABSTRAK

Satu kajian eksperimen bertajuk "Kesan langsung pemendapan logam daripada keluli tahan karat 308 LSi wayar pada keluli tahan karat 304 plat asas" dikaji. Tujuan kajian ini adalah untuk menyiasat bagaimana parameter pemendapan menjejaskan mikrostruktur, dimensi kimpalan dan kekerasan mikro daripada keluli tahan karat bahan pemendapan. Proses pemendapan logam dijalankan dengan menggunakan kaedah kimpalan tungsten robot gas lengai (TIG). Pengetahuan latar belakang pemendapan logam termasuk kimpalan, sumber haba, bahan dan aplikasi komersial berhubung dengan proses logam pemendapan, parameter proses, sifat mikrostruktur, dimensi kimpalan dan variasi kekerasan juga dikaji. Kaedah eksperimen melibatkan memanipulasi dua faktor (parameter pemendapan logam iaitu kelajuan kimpalan dan arus elektrik kimpalan) untuk menentukan jika perubahan dalam pembolehubah ini punca berubah ke arah jawapan (nilai microhardness dan kimpal ketinggian manik). Kaedah ini bergantung kepada Reka bentuk Eksperimen (DOE) dengan menggunakan Metodologi Response Surface (RSM) dan proses ini berdasarkan Central Komposit Designs (CCD) untuk mencapai pengoptimuman parameter semasa menjalankan penyelidikan eksperimen ini. Kemudian, ia telah membuktikan bahawa apabila menggunakan input haba yang tinggi, ia menyebabkan ketinggian manik kimpal yang lebih tinggi apabila arus elektrik (120 Ampere) dan kelajuan (50 mm / min) dilaksanakan. Bagi microhardness, input haba yang rendah menyebabkan prestasi yang lebih baik apabila arus elektrik (135 Ampere) dan kelajuan (170,71 mm / min) digunakan. Selain itu, perubahan microhardness pada pemendapan bahan, HAZ dan asas logam yang dimendapkan telah dibincangkan. Purata nilai microhardness menunjukkan bahawa nilai kenaikan microhardness daripada bahan pemendapan ke logam asas. Ia juga telah membuat kesimpulan bahawa kelajuan kimpalan menyumbang faktor yang paling penting untuk ketinggian manik kimpal, manakala arus elektrik kimpalan menyumbang faktor yang paling penting bagi microhardness.

ABSTRACT

An experimental research titled "Effect of Direct Metal Deposition of Stainless Steel 308 LSi Wire on Stainless Steel 304 Base Plate" is studied. The aim of this study is to investigate how parameters of deposition affecting microstructure, weld dimension and microhardness of stainless steel deposited material. The metal deposition process had been conducted using robotic tungsten inert gas (TIG) welding method. Background knowledge of metal deposition including welding, heat source, materials and its commercial application in relation to metal deposition process, process parameters, microstructure properties, weld dimension and hardness variation were also reviewed. The experimental method involving manipulating two factors (metal deposition parameters which are welding current and welding speed) to determine if changes in these variables causes change towards the responses (microhardness value and weld bead height). This method relies on Design of Experiment (DOE) by using Response Surface Methodology (RSM) and the process is based on Central Composite Designs (CCD) in order to achieve optimization of parameters while conducting this experimental research. Then, it was proved that when using high heat input, it resulted to higher weld bead height when current (120 Ampere) and speed (50 mm/min) had been setup. As for microhardness, low heat input resulting a better performance of microhardness when current (135 Ampere) and speed (170.71 mm/min) were setup. Besides that, microhardness variation which was indented at the deposited material, HAZ and base metal were discussed. The average microhardness value showed that the microhardness value increases from deposited material to base metal. It is also concluded that the welding speed contributes the most significant factor for weld bead height, while welding current contributes the most significant factor for microhardness.

DEDICATION

To
my beloved father, Hj Mohd Nizam bin Abdul Rashid
my appreciated mother, Hjh Sa'adiah binti Abu Hassan
my adored brother and sister, Mohd Syazni bin Mohd Nizam and Syazana binti Mohd Nizam
for giving me moral support, cooperation, encouragement and also understandings
Thank You So Much & Love You All Forever

ACKNOWLEDGEMENT

In the name of ALLAH, the most gracious, the most merciful, with the highest praise to Allah that I manage to complete this final year project successfully even though there are difficulties in completing this study.

My respected supervisor, Prof Madya Dr. Nur Izan Syahriah binti Hussein for the great mentoring that was given to me throughout this project. Besides that, I would like to express my gratitude to my respected co-supervisor, Mr. Mohamad Nizam bin Ayof for a kind supervision, advice and guidance as well as exposing me with meaningful experiences throughout the study.

I would also like to acknowledge with much appreciation to my family and friends for their understandings, supports and beneficial discussion in completing this FYP report.

Finally, I would like to thank everybody who was important to this FYP report, as well as expressing my apology that I could not mention personally each one of you.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

3D	-	Three Dimensional
ANOVA	-	Analysis Of Variance
ASTM	-	American Society for Testing and Materials
CAD	-	Computer Aided Design
CCD	-	Central Composite Design
DCEN	-	Direct Current Electrode Negative
DOE	-	Design of Experiment
EDM	-	Electrical Discharge Machining
FA	-	Ferrite Austenite
GMAW	-	Gas Metal Arc Welding
GTAW	-	Gas Tungsten Arc Welding
HAZ	-	Heat Affected Zone
HV	-	Vickers Hardness
MIG	-	Metal Inert Gas
RSM	-	Response Surface Methodology
SEM	-	Scanning Electron Microscopy
SMAW	-	Shielded Metal Arc Welding
TIG	-	Tungsten Inert Gas

LIST OF SYMBOLS

µm	-	Micron Metre
%	-	Percentage
A	-	Ampere
Ar	-	Argon
C	-	Carbon
Cr	-	Chromium
Fe	-	Iron
H_2	-	Hydrogen
He	-	Helium
Hz	-	Hertz
kgf	-	Kilogram.Force
kJ/mm	-	Kilo Joule per millimeter
mm	-	Millimeter
mm/min	-	Millimeter per minutes
Mn	-	Manganese
Mo	-	Molybdenum
Ni	-	Nickel
P	-	Phosphorus
S	-	Sulfur
S	-	Second
Si	-	Silica
V	-	Voltage
wt%	-	Weight Percentage

CHAPTER 1

INTRODUCTION

1.1 Introduction

Direct metal deposition is a process of depositing additive material onto substrate material in which the process is implemented based on different purpose that comprise of direct part production, surface modification and repair. It can also be known as cladding, hard facing and welding overlays. Direct metal deposition process may also alter the properties of substrate due to repeated of heating and cooling process. In addition, direct metal deposition is being implement in order to eliminate surface corrosion, fatigue, cracks, improve wear resistance and hardness of substrate material.

1.2 Background of Study

This project is related to the effect of deposition of stainless steel 308 LSi wire on stainless steel 304 base plate. Experimental procedures were selected as a methodology of this project. Throughout the experiment, stainless steel 304 base plate and built structure from stainless steel 308 LSi wire undergone testing in order to achieved the effect of metal deposition parameters.

In presence, it is a common method of implementing metal deposition for parts restoration, direct parts production and improve surface of materials by adding material layer-by-layer to achieve the desired or a near-net shape. Metal deposition process is patented originally by Rolls Royce which it is a technology in manufacturing process. Computer Aided Design (CAD) is used in building directly a complex part without aid from tools. In contrast with traditional machining method, metal deposition process only require wire in producing the parts which contributes a lot in reducing lead time, waste of material and cost efficiency (Bonaccorso *et al.*, 2011).

A high deposition rate and improvement of material performance are potential advantages that is being expected by the wire feedstock. In this study, robot Gas Tungsten Arc Welding (GTAW) or also known as Tungsten Inert Gas (TIG) was selected as a heat source and filler wire is stainless steel. The use of welding process was reported in this paper.

The aim of the experimental investigation is to study the characteristics of stainless steel 304 after deposition by stainless steel 308 LSi. For this purpose, stainless steel 308 LSi was deposited on stainless steel 304 with different values of welding current and welding speed. Microstructure, weld bead height and microhardness of deposited material were studied as respond from different values of welding current and welding speed. Heat input is also being calculated for better understanding towards cooling rates.

1.3 Problem Statement

Stainless steel 304 is a material that is useful for structural engineering as it has its specific properties such as good corrosion resistance and good weldability (Mirshekari *et al.*, 2014). These advantages are related to the used of this material as components in transportation, aerospace and turbine industries. Despite all of these, this material experiences limitations of performance in their applications due to fatigues and overload operating condition, causing it to have wear failures and deep cracks (Song *et al*., 2016). Besides that, there is also a possibility that the component is subjected to impacts, stress and corrosion, resulting to crack and defect (Pinkerton *et al*., 2008). Thus, surface restoration can be done in order to achieve the performance of stainless steel 304 materials instead of discarding it as useless components. Deposition of stainless steel 308 LSi filler wire on stainless steel 304 base plate by using TIG welding is proposed in order to investigate the effect of the method towards the material, in terms of hardness and height of weldment. Height of weldment can be a factor to determine the number of layers is needed in order to achieve the desired shape.

1.4 Objectives

The objectives of this study are:

i) To study the effect of deposition parameters on weld bead height and microhardness of the deposited material.

ii) To characterize the microstructure of deposited stainless steel 308 LSi wire on stainless steel 304 base plate.

1.5 Scope of Study

There are two material involves in this study which are stainless steel 304 and stainless steel 308 LSi wire. Stainless steel 304 is the substrate while stainless steel 308 LSi is the filler wire that function as a deposition material or build structure. Stainless steel 304 had been deposited by stainless steel 308 LSi wire through welding by using robot TIG as a heat source. In order to observe the effect on microstructure, weld bead height and microhardness of the material, two parameters were selected which are welding current and welding speed. The experiment was carried out by using Design of Experiement (DOE) by Response Surface Methodology (RSM) method.

Microhardness properties of deposition had been examined by using Vickers microhardness in accordance with ASTM E92-82. For microstructure observation, model ZEISS of Optical Microscope had been used. A sample preparation for microstructural had been done according to ASTM 112. Other aspect which is weld dimension and heat input were also included in this study.

CHAPTER 2

LITERATURE REVIEW

This chapter presents a review based on literatures related to welding, deposition process, stainless steel materials and also metal deposition parameters. Besides that, literature related to TIG as a heat source, weld dimension, microstructure, microhardness and design of experiment also being included in this chapter.

2.1 Welding

Joining is a process that joints two material or parts. For instance, bolt and nut is use to joint parts for a chair. This is a joining process by means of mechanical. Another joining process is welding. Welding is a process of joining a similar or dissimilar materials by using heat or pressure. Figure 2.1 shows a welding process. In presents, welding is a favorable method by industries as it provides a high strength of joints (Mirshekari *et al.*, 2014). Filler material is used in welding process in order to form weld pool during melting of base metal. When the weld pool reaches solidification, it builds a strong joint with the base material, allowing high strength properties to be achieved.

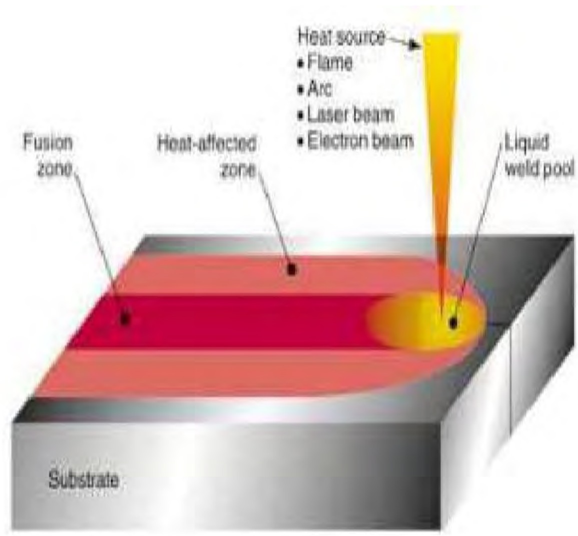

Figure 2.1: Welding process (Singh *et al*., 2014)

2.1.1 Arc Welding

Arc welding is a process that use electric arc which produces extreme heat to melt the material and electrode wire, that contribute the joining process to occur. Electrode is used in arc welding process to conduct electrical energy from electric arc and it also provides filler metal when it melts. The types of arc welding includes shielded metal arc welding (SMAW), gas metal arc welding (GMAW) and gas tungsten arc welding (GTAW).

Shielded metal arc welding which is also known as stick welding uses an electric arc and consumable coated electrodes that act as filler metal for welding a stainless steel. Equipment for SMAW is relatively low but it also has a low deposition rates causing it to have a slow welding process due to a repeated replacement of electrodes (The Lincoln Electric Company, 2003).

Gas metal arc welding is also known as a metal inert gas (MIG) uses a continuous fed electrode wire to melt and joints material through heat source from electric arc. Inert gas works as a protection towards the electrode wire to avoid any contamination from the welding process. MIG is highly recommended for the process of thick material with long joints as it has high deposition rates (The Lincoln Electric Company, 2003)

Gas tungsten arc welding or it is also called as tungsten inert gas (TIG) uses tungsten as the electrode. The electrode is non-consumable while the inert gas works as shield to avoid any defect towards the weldment.

2.1.2 Tungsten Inert Gas (TIG)

TIG welding is a method that the heat produced through metal substrate and a non-consumable electrode made of tungsten. Figure 2.2 shows welding process by using TIG. The electrode is a part of the weld as that melt from the base metal due to the sufficient heat produced from electric arc and it leads to the production of the weld pool and it leaves no slag. The inert gas perform in covering the arc area in order to protect weld pool free from defects and porosity (Prajapati and Shah, 2016). In addition, TIG welding is a process that produced a high quality and good appearance of weldment (Prajapati and Shah, 2016).

As for the shielding gas, there are mixtures of argon (Ar), helium (He) and hydrogen (H_2). Argon is basically used for stainless steel, mild steel, aluminum and titanium as it able to perform at a high arc voltage. Helium can be used for stainless steel and it offers a small heat affected zone causing a deeper penetrations. Helium can also be mix with argon. Helium promotes a high input of heat for increasing the speed of welding. As for hydrogen, it should not be applied to a martensitic, ferritic and duplex stainless steel as it may demolish electrode. As for the selection of shielding gas, it is depends on the base material. According to Kumar *et al*. (2015a); Mirshekari *et al*. (2014); Bonaccorso *et al*. (2011); SHIRI *et al*. (2012), the suggested shielding gas for stainless steel 304 base plate is Argon.