UNIVERSITI TEKNIKAL MALAYSIA MELAKA

THE EFFECTS OF METAL INERT GAS (MIG) PROCESS CONDITION ON HARDNESS OF STAINLESS STEEL CLADDINGS OF A CARBON STEEL SUBSTRATE

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

by

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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). The members of the supervisory committee are as follow:

……………………………….

Main Supervisor

(Dr. Nur Izan Syahriah Binti Hussein)

(Official Stamp)

DECLARATION

I hereby, declared this report entitled "The Effects of Metal Inert Gas (MIG) Process Condition on Hardness of Stainless Steel Claddings of a Carbon Steel Substrate" is the results of my own research except as cited in references.

Signature : …………………………….....

Author's Name : Azri Safwan Bin Abdul Halim

Date : 18 May 2011

ABSTRACT

An experimental research titled "The effect of MIG process conditions on hardness of stainless steel claddings of a carbon steel substrate" has been carried out. The overall aim is to investigate how different deposition parameters affected macrostructure, microstructure and hardness variation of stainless steel deposited material. The cladding process will be conducted using metal inert gas (MIG) weld method. Background knowledge about metal deposition including form of materials, heat sources and its commercial application in relation to its cladding, process parameter, microstructure properties, hardness variation, and macrostructure also reviewed. This experimental method involves manipulating one variable (cladding parameter) to determine if changes in this variable cause changes in another variable (hardness variation). This method relies on controlled methods and the manipulation of variables to test a hypothesis. Finally, the hardness variation of cladding stainless steel was inspected using Rockwell test. In addition, Design Expert Software that implemented response surface methodology technique has been used in order to make sure the optimization of parameters while conducting this experimental research. This research had successfully analyzed the data collected from this experimental research. The effect of welding parameters such as current, voltage and travel speed are directly affected hardness variations of carbon steel cladding material. Finally, the suggestion to enhance the optimization of parameter in cladding process also had been discussed.

ABSTRAK

Sebuah penelitian eksperimental berjudul "Pengaruh keadaan proses MIG pada kekerasan kelongsong stainless steel dari substrat baja karbon" telah dilakukan. Objektif umumnya adalah untuk menyiasat bagaimana parameter deposisi yang berbeza berpengaruh macrostructure, mikro dan variasi kekerasan disimpan bahan stainless steel. Proses cladding akan dilakukan menggunakan logam inert gas (MIG) kaedah las. Latar belakang pengetahuan tentang pengendapan logam termasuk dalam bentuk bahan, sumber panas dan aplikasi komersil dalam hubungannya dengan cladding nya, parameter proses, sifat mikro, variasi kekerasan, dan macrostructure juga disemak. Kaedah eksperimen melibatkan memanipulasi satu variabel (parameter cladding) untuk menentukan sama ada perubahan ini menyebabkan perubahan pembolehubah dalam pembolehubah lain (variasi kekerasan). Kaedah ini bergantung pada kaedah dikendalikan dan manipulasi pembolehubah untuk menguji hipotesis. Akhirnya, variasi kekerasan cladding stainless steel diperiksa menggunakan uji Rockwell. Selain itu, Ahli Design Software yang respon permukaan teknik dilaksanakan metodologi telah digunakan dalam rangka untuk memastikan pengoptimuman parameter ketika melakukan kajian eksperimental. Penyelidikan ini telah berjaya menganalisis data yang dikumpul daripada kajian ini eksperimental. Pengaruh parameter pengelasan seperti arus, voltan dan kelajuan perjalanan secara langsung terkena kesan variasi kekerasan baja karbon cladding material. Akhirnya, cadangan untuk meningkatkan optimasi parameter dalam proses cladding juga telah dibincangkan.

DEDICATION

For my beloved family:

Abdul Halim Bin Mohd Salleh

Siti Sabariah Binti Muhammad Syariff

For my adored friends:

Muhammad Rabani Bin Othaman

Amzar Bin Mat Yunus

Azhar Bin Abdol Aziz

Muhammad Aiman Bin Yusof

Muhd Ammar Bin Hassan

Syukri Zarizi Bin Kamaruzan

Muhammad Ikhwan Bin Muhammad

Kamarul Syaufi Bin Rasidi

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LIST OF ABBREVIATIONS

CAD - Computer-Aided Design

CRES - Corrosion-Resistant Steel

DMD - Direct Metal Deposition

GMA - Gas Metal Arc

GMAW - Gas Metal Arc Welding

GTA - Gas Tungsten Arc

GTAW - Gas Tungsten Arc Welding

HAZ - Heat Affected Zone

LENS - Laser Engineered Net Shaping

MIG - Metal Inert Gas

RSM - Response Surface Methodology

SEM - Scanning Surface Microscopy

TIG - Tungsten Inert Gas

AISI - American Iron Standard Institute

AWS - American Welding Society

ASTM - American Society for Testing and Materials

DOE - Design of experiment

CHAPTER 1

INTRODUCTION

1.1 Introduction

Cladding is a well established process used in a variety of industries for improving the surface and near surface properties (wear, corrosion or heat resistance) of a part, or to resurface a component that has become worn through use. Cladding typically involves the creation of a new surface layer having different composition than the base material, as opposed to hardening which simply entails changing the properties of the substrate itself in a thin surface layer. There are currently quite a number of different techniques for performing cladding each with its own specific characteristics in terms of the materials employed, the quality of the clad layer and various practical issues including throughput speed, process compatibility, and cost. Laser based processes are amongst these techniques however, their implementation has been limited to both cost and various implementation factors.

Over the past several years, a new type of cladding tool based on high power diode lasers has become available. In many instances, this technology offers superior overall clad quality, reduced heat input, minimal part distortion and better clad deposition control than traditional technology, while also delivering lower operating cost and easier implementation than other laser based methods. Figure 1.1 shows a schematic of the High Power Diode Laser system.

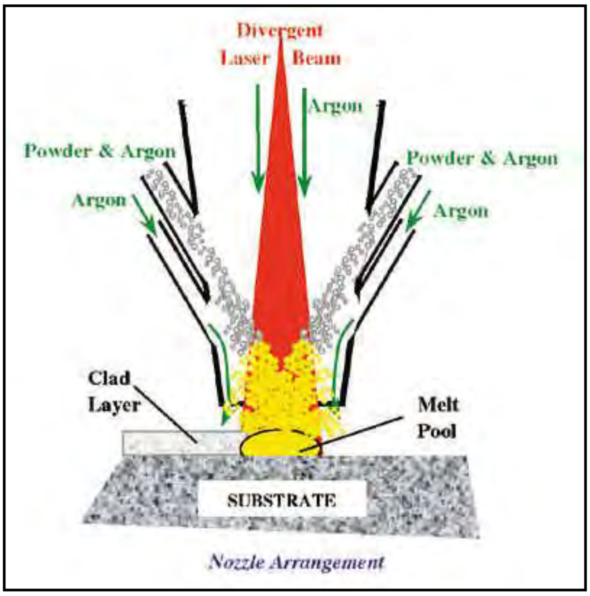

Figure 1.1: High Power Diode Laser System (Neill Boyle, Aidan Kennedy & John Connolly (1999)).

1.2 Background of Problem

To improve the surface properties of metallic mechanical parts, such as the resistance against wear and corrosion, several thermal surface treatments are available for instance are flame spraying, plasma spraying and arc welding are established techniques. Characteristic for these techniques is the application of a surface layer with the required properties on top of a cheap material without those properties. Depending on the applied technique, common problems are a combination of a poor bonding of the applied surface layer to the base material, the occurrence of porosity, the thermal distortion of the work piece, the mixing of the surface layer with the base material and the inability of a very local treatment.

The techniques that overcome these problems are laser cladding. Laser cladding has been defined as "a process which is used to fuse with a laser beam another material which has different metallurgical properties on a substrate, whereby only a very thin layer of the substrate has to be melted in order to achieve metallurgical bonding with minimal dilution of added material and substrate in order to maintain the original properties of the coating material" (Komvopoulos, 1990).

1.3 Problem Statement

Based on this study, several main points need to be focused and questions need to be answered at the end of the topic:

i. How different deposition parameters affected macrostructure and microstructure of stainless steel deposited material?
ii. How different deposition parameters affected hardness of stainless steel deposited material?

1.4 Objectives

Objectives of this study are as follows:

i. To investigate how different deposition parameters affected macrostructure and microstructure of stainless steel deposited material.
ii. To investigate how different deposition parameters affected hardness of stainless steel deposited material.
iii. To establish whether stainless steel can be deposited as cladding using MIG as heat source.

1.5 Overview of the Dissertations

Chapter 1 provide fundamental of cladding process and its applications. In addition, background of this research also reviewed in this chapter. Problem statement and objectives of this experimental research are stated based on the task given.

Chapter 2 presents a review of the literature about the effect of (MIG) process condition on dilution of stainless steel claddings of a carbon steel substrate. Beside, the literature about Metal Inert Gas (MIG) heat source and process also review in this chapter. Background knowledge about stainless steel material is also provided in relation to its process parameter, dilution, and macrostructure and hardness variation. Summary of literature review is provided at the end of this chapter.

Chapter 3 describes an experimental method of this research including design of experiment, experimental flow, equipment set up and technique used. Introduction on some method and approach in selecting an optimize parameters for this experimental research also stated in this report. This chapter provides statistical analysis of direct metal deposition. The conclusion of this chapter would interpret as research flow along this research.

Chapter 4 describes the result of the design of experiment. Interpretation on some result and finding of this research also stated in this chapter. This chapter provides statistical analysis of the design of experiment. The main parameters of the process are current, voltage and travel speed. These parameters are not independent.

Chapter 5 describes a macrostructure, microstructure development and hardness variations of as-deposited stainless steel using wire feed method. Introduction on some method and approach in determining macrostructure, microstructure development and hardness variations of as-deposited also stated in this report. This chapter provides interpretation of experiment result and its discussion.

Chapter 6 describes a conclusion of this research including interpretation of overall research flow. The overall research objectives, scope, findings and discussions also conclude in this chapter. Finally, this chapter provides recommendation of future works.

1.6 Activity Planning

The used of Gantt chart is an effective tool for planning and scheduling operations involving a minimum of dependencies and interrelationships in this experimental research. On the other hand, the charts are easy to construct and understand, even though they may contain a great amount of information. In general, the charts are easily maintained provided the task requirements are somewhat static. Updating of a Gantt chart will reveal difficulties encountered in the conduct of this experimental project. Gantt chart of this experimental research is provided in Appendix A.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter presents a review of the literature about the effect of (MIG) process condition on dilution of stainless steel claddings of a carbon steel substrate. Beside, the literature about metal inert gas (MIG) heat source and process also review in this chapter. Background knowledge about stainless steel material is also provided in relation to its process parameter, macrostructure properties, microstructure properties and hardness variation. Summary of literature review is provided at the end of this chapter.

2.2 Metal Inert Gas (MIG)

MIG welding or GMAW is a process that melts and joints metals by joint metal by heating them with an arc established between a continuously fed filler wire electrode and the metals as shown in figure 2.1.

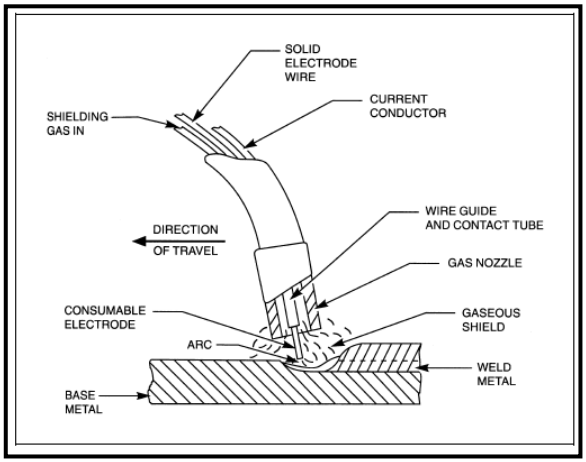

Figure 2.1: Metal Inert Gas Process (O’Brien, RL (1997)).

Shielding of the arc and the molten weld pool is often obtained by using inert gases such as argon or helium. This process applied a continuous and consumable wire electrode. Carbon dioxide or argon-oxygen mixtures are suitable for arc shielding when welding the low-carbon and low-alloy steels, while pure inert gas may be essential when welding highly alloyed steels (Kou, 2003).

Pure inert gas shielding is essential for welding alloys of aluminum, magnesium, copper, titanium, zirconium, stainless steels and nickel base super alloys. MIG welding is normally perform with direct current electrode positive because it provides a stable arc, smooth metal transfer, relatively low spatter loss and good weld characteristics. The gas metal arc process or metal inert gas process can be used for spot welding to replace either riveting, electrical resistance or GTA (TIG) spot welding (Lincoln Arc Welding 2001).

Originally developed for welding aluminum and other non-ferrous materials in the 1940s, MIG was soon applied to steels because it allowed for lower welding time compared to other welding processes. The cost of inert gas limited its use in steels until several years later, when the use of semi-inert gases such as carbon dioxide became common (Lincoln Arc Welding Foundation, 2001).

Advantages of using MIG welding according to Lincoln Arc Welding Foundation, (2001) are as follows:

a) Very clean due to the application of inert shielding gas
b) Higher deposition rate, thicker work pieces can be welded at higher speed
c) Can master the welding skill in short time

2.3 Stainless Steel

In metallurgy, stainless steel, also known as inox steel or inox, is defined as a steel alloy with a minimum of 11% chromium content by mass. Stainless steel does not stain, corrode, or rust as easily as ordinary steel (it *stains less*, but it is not stain-proof). It is also called corrosion-resistant steel or CRES when the alloy type and grade are not detailed, particularly in the aviation industry. There are different grades and surface finishes of stainless steel to suit the environment to which the material will be subjected in its lifetime. Common uses of stainless steel are cutlery and watch cases and bands.

Stainless steel differs from carbon steel by the amount of chromium present. Carbon steel rusts when exposed to air and moisture. This iron oxide film (the rust) is active and accelerates corrosion by forming more iron oxide. Stainless steels have sufficient amounts of chromium present so that a passive film of chromium oxide forms which prevents further surface corrosion and blocks corrosion from spreading into the metal's internal structure.

2.3.1 Stainless steel composition

Stainless steel AISI 304 and 304L has a composition as shown below (Table 2.1) (Balbaud, 2007).

Table 2.1: Chemical composition of the 304L stainless steel in wt% (Balbaud, 2007).

	Type 304 %	Type 304L %
Carbon	0.08 max.	0.03 max.
Manganese	2.00 max.	2.00 max.
Phosphorus	0.045 max.	0.045 max.
Sulfur	0.030 max.	0.030 max.
Silicon	0.75 max.	0.75 max.
Chromium	18.00-20.00	18.0-20.0
Nickel	8.00-12.00	8.0-12.0
Nitrogen	0.10 max.	0.10 max.
Iron	Balance	Balance

Table 2.2: Mechanical Properties of the 304L stainless steel in wt% (Balbaud, 2007).

	UTS Ksi (MPa)	0.2% YS Ksi (MPa)	Elongation % in 2" (50.8 mm)	Hardness Rockwell
Type 304L	85 (586)	35 (241)	55	B80
Type 304	90 (621)	42 (290)	55	B82

Stainless steel AISI 304L has a wide variety of applications in a condition where the following properties are important:

a) Resistance to corrosion
  - These steels exhibit excellent resistance to a wide range of atmospheric, chemical, textile, and petroleum and food industry exposures.

b) Resistance to oxidation
  - The maximum temperature can be exposed continuously without appreciable scaling is about 1650°F (899°C). For intermittent exposure, the maximum exposure temperature is about 1500°F (816°C).

c) Ease of fabrication
d) Excellent formability
e) Ease of cleaning
f) High strength with low weight
g) Good strength and toughness at cryogenic temperatures
h) Readily available of a wide product forms

Lee, (2006) specified that for AISI 304L stainless steel, because of the advantages it has in mechanical and anti-corrosion properties, the area of its application has been widely engaged in chemical, automotive and nuclear industries. In practical, AISI 304L stainless steel weldments are often required to operate in a dynamic mode, and consequently they are frequently subjected to impact forces. Therefore, these components require a design that has to be fully understood of the impact response and fractured characteristics of the 304L stainless steel weldments.