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BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: **Direct Metal Deposition of Stainless Steel using Wire Feed Method: An Experimental Study on Microstructural Development and Microhardness**

SESI PENGAJIAN: 2009/2010 Semester 1

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DIRECT METAL DEPOSITION OF STAINLESS STEEL USING WIRE FEED METHOD: AN EXPERIMENTAL STUDY ON MICROSTRUCTURAL DEVELOPMENT AND MICROHARDNESS VARIATIONS

Thesis submitted in accordance with the partial requirements of the Universiti Teknikal Malaysia Melaka for the Bachelor of Manufacturing Engineering (Manufacturing Process) with Honours

By

MOHD SEIFUL EZUAN BIN SAYUTI

Faculty of Manufacturing Engineering

APRIL 2010

DECLARATION

I hereby, declared this report entitled "Direct Metal Deposition of Stainless Steel using Wire Feed Method: An Experimental Study on Microstructural Development and Microhardness Variations" is the results of my own research except as cited in references.

Signature	:	……………………………....
Author's Name	:	Mohd Seiful Ezuan Bin Sayuti
Date	:	19 April 2010

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

……………………………….

Main Supervisor

(Dr. Nur Izan Syahriah Binti Hussein)

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ABSTRACT

An experimental research titled “Direct Metal Deposition of Stainless Steel using Wire Feed Method: An Experimental Study on Microstructural Development and Microhardness Variations” has been carried out. The overall aim is to investigate how different deposition parameters affected microstructure and hardness variation of stainless steel deposited material. The deposition process will be conducted using metal inert gas (MIG) weld method. Background knowledge about direct metal deposition including form of materials, heat sources and its commercial application in relation to its welded, process parameter, microstructural properties and microhardness variation also reviewed. This experimental method involves manipulating one variable (deposition parameter) to determine if changes in this variable cause changes in another variable (microstructure and hardness variation). This method relies on controlled methods and the manipulation of variables to test a hypothesis. Finally, the hardness variation of as-deposited stainless steel was inspected using Rockwell test and its microstructure behavior was inspected using optical microscopy. 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, arc voltage and travel speed are directly affected microstructural development and microhardness variations of stainless steel deposited material. Finally, the suggestions to enhance the optimization of parameter in direct metal deposition also had been discussed.

ABSTRAK

Kajian yang bertajuk “Direct Metal Deposition of Stainless Steel using Wire Feed Method: An Experimental Study on Microstructural Development and Microhardness Variations” telah pun dilaksanakan. Objektif utama perlaksanaan kajian ini adalah untuk menyiasat bagaimana parameter keladak timbunan mempengaruhi pembangunan struktur mikro dan ciri-ciri mekanikalnya terhadap bahan besi tidak bercacat. Proses keladak timbunan akan dilaksanakan menggunakan kaedah kimpalan gas logam tidak giat. Latar belakang tentang pengetahuan di dalam keladak timbunan logam secara terus termasuk bentuk bahan yang digunakan, sumber haba dan aplikasi komersialnya serta kesannya terhadap parameter proses turut dibincangkan. Eksperimen ini memanipulasikan pemboleh ubah (parameter keladak timbunan) terhadap perubahan yang berlaku kepada pemboleh ubah yang bergerak balas iaitu struktur mikro dan variasi kekerasan. Ujikaji ini bersandar kepada kaedah kawalan dan manipulasi terhadap pemboleh ubah untuk menguji hipotesisnya. Akhirnya, variasi kekerasan akan diuji menggunakan ujian Rockwell dan struktur mikronya akan diuji menggunakan Optical Microscopy. Tambahan, penggunakan perisian Design Expert yang mengimplikasikan kaedah respon permukaan telah digunakan untuk menentukan penggunaan parameter yang optimum di dalam melaksanakan kajian ini. Kajian ini telah berjaya menganalisa kesemua data yang diperolehi daripada ujikaji yang dijalankan. Parameter proses seperti arus elektrik, voltan dan kelajuan perjalanan sangat mempengaruhi struktur mikro dan variasi kekerasan keladak timbunan yang terhasil. Akhir kata, cadangan untuk meningkatkan tahap optimum parameter yang digunakan di dalam eksperimen ini turut dibincangkan.

DEDICATION

For my beloved family:

Sayuti Bin Dollah

Sao’dah Binti Awang

Norfazila Binti Sayuti

For my adored friends:

Noor Aniza Binti Norrdin

BMFP’s Students

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بسم الله الرحمن الرحيم

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Also with the greatest thanks to my beloved parents and family who always pray and give the encouragement while pursuing my research and project. Their sacrifices are never being forgotten.

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TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF GRAPHS

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

Direct Metal Deposition (DMD) refers to an additive layered manufacturing technology for building components from a Computer-Aided Design (CAD) model. These processes have been proven feasible for fabricating components from nearly any metal system to near-net shape accuracy with mechanical properties approaching and in some cases exceeding the properties found in conventionally processed wrought structures. Single step processing by DMD technique produce cost savings realized by elimination of conventional multi-step thermo-mechanical processing. Design features such as internal cavities or over-hanging features can be made without joined assemblies. Hard to process materials such as intermetallics, refractory metals, and high temperature alloys can be processed in a single step. Functionally graded compositions can be created within three-dimensional components to vary the properties to match localized requirements due to the service environment. One of the processes that widely used in direct metal deposition is High Power Diode Laser (HPDL). Figure 1.1 shows a schematic of the High Power Diode Laser (HPDL) system.

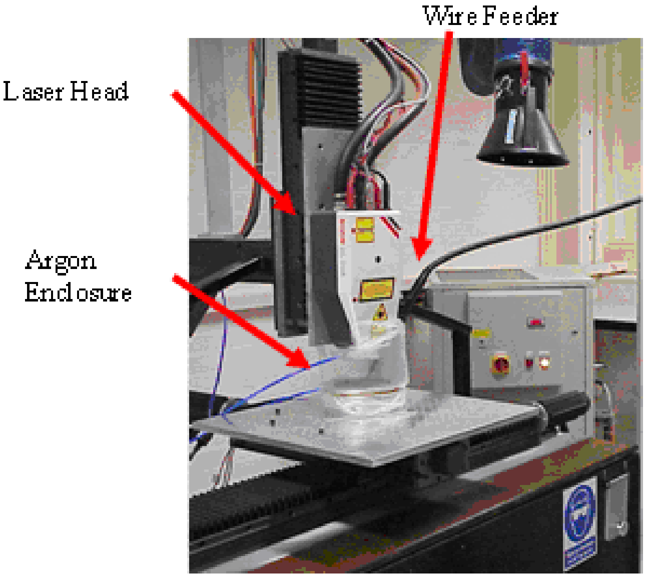

Figure 1.1: High Power Diode Laser (HPDL) System (Hussein 2008).

The technology offers the designer a rapid prototyping capability at the push of a button, without the need to fabricate dyes or use forming equipment or extensive machining and joining processes to produce a part. Future development is still required for these processes to be commercially accepted and used in industry. Parts are deposited with a surface roughness of certain value, arithmetic average, making a secondary finishing operation necessary for some applications to achieve high accuracy and polished surface texture.

This research work is carried out as an experimental study. The information used for conducting this research work is real and not hypothetical.

1.2 Background of Problem

Since the first introduction of rapid prototyping in 1986, J. Mazumder (2008) specified that several techniques have been developed and successfully commercialized in the market. However, most commercial systems currently use resins or waxes as raw materials. Thus, the limited mechanical strength for functional testing is regarded as an obstacle towards broader application of rapid prototyping techniques. To overcome this problem, direct metal deposition methods are being investigated worldwide for rapid prototyping and even for rapid tooling applications. As a contribution to this development, a fundamental study on a process combination of wire feeding method (using Metal Inert Gas, MIG) and the use of robotic welding technique is reported in this paper. Robotic welding enables accurate deposition of metals. Compared to powder, the use of wire is of advantage in terms of a simple feeding mechanism as well as a higher deposition rate (Li 2006).

The main focus of the experimental investigation is to find the basic process characteristics. For this purpose, basic parts were fabricated as a function of process parameters such as current, travel speed and arc voltage. The microstructure and hardness are then examined as a function of these process parameters. In conclusion, the advantages and disadvantages of this process are discussed in comparison with other direct metal fabrication techniques.

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 study:

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

1.3.1 Objectives

Objectives of this study are as follows:

i. To investigate how different deposition parameters affect microstructure of stainless steel deposited material.
ii. To investigate how different deposition parameters affect hardness variation of stainless steel deposited material.

1.3.2 Importance of Study

The idea of this study is to emphasize an experimental study of Direct Metal Deposition (DMD). Direct metal deposition is one of the latest techniques in fabricating part. Presents a general overview of the DMD of stainless steel by using wire feed method. The effect of different deposition parameters that affected microstructure and hardness variation of stainless steel deposited material are discussed. The interfaces between various techniques in direct metal deposition are also discussed with several examples during this project. On the other hand, this project will reveal about the importance of DMD techniques in terms of development of rapid prototyping technology. It is also as early preparation before we adapt our real future undertaking.

1.4 Overview of the Dissertations

Chapter 1 provide fundamental of direct metal deposition 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 direct metal deposition including form of materials, heat sources and its commercial application. 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 welded, process parameter, microstructural properties and microhardness 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. Furthermore, 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. Furthermore, 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. The current and voltage, for example, are correlated by the arc characteristic curves.

Chapter 5 describes a microstructural development and microhardness variations of as-deposited stainless steel using wire feed method. Introduction on some method and approach in determining microstructural development and microhardness variations of as-deposited also stated in this report. Furthermore, 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.

1.5 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 direct metal deposition including form of materials, heat sources and its commercial application. 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, microstructural properties and microhardness variation. Summary of literature review is provided at the end of this chapter.

2.2 Direct Metal Deposition Process

Direct metal deposition (DMD) refers to the additive layered manufacturing technology for building components from a computer-aided design (CAD) model. These processes have been proven feasible for fabricating components from nearly any metal system to near-net shape accuracy with mechanical properties approaching and in some cases exceeding the properties found in conventionally processed wrought structures. Mazumder, (2008) specified that single step processing by DMD technique produce cost savings realized by elimination of conventional multi-step thermo-mechanical processing. Design features such as internal cavities or over-hanging features can be made without joined assemblies. Hard to process materials such as intermetallics, refractory metals, and high temperature alloys can be processed in a single step. Functionally graded compositions can be created within