UNIVERSITI TEKNIKAL MALAYSIA MELAKA

HARDNESS VARIATION OF HEAT TREATED LAYER-BY-LAYER DEPOSITED NICKEL BASED ALLOY

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

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I hereby, declared this report entitled "Hardness Variation of Heat Treated Layer-By-Layer Deposited Nickel Based Alloy" is the results of my own research except as cited in references.

Signature	:	………………………………………….
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Date	:	29 JUNE 2012

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 member of the supervisory is as follow:

………………………………

(Dr. Nur Izan Syahriah binti Hussein)

ABSTRAK

Proses pemendapan lapisan demi lapisan oleh DMD akan menghasilkan sifat-sifat bahan yang tidak homogen pada bahan yang telah didepositkan. Dalam kajian ini, kimpalan gas lengai tungsten akan digunakan untuk menjalankan proses pemendapan pada Waspaloy. Sifat bahan yang tidak homogen akan dibentuk daripada pemendapan lapisan demi lapisan Waspaloy disebabkan pengedaran haba yang dinamik semasa process pemendapan. Oleh itu, pelbagai prosedur rawatan haba akan diberikan kepada dua sampel iaitu logam tempayan Waspaloy dan Waspaloy yang didepositkan. Dalam pembelajaran ini, kesan daripada suhu dan masa rawatan haba pada mikrostruktur dan kekuatann dua bahan tersebut. Sample yang telah diuji dengan rawatan haba larutan (solution treatment) telah menunjukkan kekerasan yang rendah berbanding dengan sampel yang diuji dengan rawatan haba larutan dan rawatan haba penuaan. Rawatan haba penuaan pada 16 jam dan 30 jam telah menunjukkan kenaikkan pada kekerasan bahan. Kekerasan telah maningkat dari 403.2HV ke 430.8HV bagi sampel yang diuji dengan rawatan haba larutan pada 1080°C. hasil dari kajian ini, rawatan haba yang optima yang boleh diuji adalah sama dengan standatd rawatan haba yang diuji pada logam tempayan Waspaloy iaitu rawatan haba larutan pada 1080°C diikuti dengan rawatan haba penuaan pertama pada 845°C dan akhirnya rawatan haba penuaan pada 760°C. masa untuk stiap rawatan haba telah meningkatkan kekerasan bahan boleh digunakan pada rawatan haba larutan selama 4 dan 25 jam, rawatan haba penuaan pertama selama 4 jam, 8jam dan 16 jam manakala untuk rawatan haba penuaan kedua adalah selama 16 jam dan 30 jam. Variasi pada setiap masa rawatan telah meningkatkan kekerassan pada bahan tersebut.

ABSTRACT

The deposition layer-by-layer of direct metal deposition will produce the inhomogeneous material properties of the deposited material. In this study, tungsten inert gas (TIG) welding process was used to conduct the deposition process on Waspaloy. The layer-by-layer deposition of Waspaloy will form the inhomogenous of the material properties because of the dynamic distribution of heat during the deposition process. Thus, various heat treatment procedure has been applied to two types of sample; as-received Waspaloy and deposited Waspaloy. In this study, the effect of heat treatment temperature and time towards the microstructure and hardness variations on two sample of Waspaloy were investigated by using optical microscope and hardness test. By undergo the solution treatment, the as-received and deposited Wasaploy had the lowest hardness and strength compared to sample that undergo solution treatment and double ageing process. The ageing process for 16 hour and 30 hour has shows the increased hardness value of the deposited sample which undergo solution treatment at 1080°C. The increase value was from 403.2HV to 430.8HV. From the study, the results has shown that the optimun heat treatment temperature were similar to the standard heat treatment that apply for wrought Waspaloy which is solution treatmemt at 1080°C followed by stabilization at 845°C and ageing process at 760°C. The time for solution treatment were 4 hour and 25 hour, stabilization were 4 hour,8 hour and 16 hour and ageing process were 16 hour and 30 hour subjected to air cool condition. The various of time in each of the treatment still give the higher value of hardness among all samples.

DEDICATION

I would like to dedicate to my family members that has giving me fully support in conducting this study.

ACKNOWLEDGEMENT

I would like to take this opportunity to thank God for giving me the chance to do this project. Besides that, I would like to appreciate and thank everybody who has contributed to the success of this experiment and technical report, especially to my Supervisor, Dr. Nur Izan Syahriah binti Hussein whom has provided me with lot of guidance and advises. My deepest gratitude goes to my family members who have provided moral support and understanding throughout the completion of this study. Last but not least, I would like to thank all the technicians whom assisted me during my experimental session especially Mr. Azhar whom have given his best cooperation and providing useful information during my experiment session. Without the cooperation from everyone, it is impossible for me to draw to a close to this study and the technical report as I can. Thank you.

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LIST OF ABBREVIATION, SYMBOLS AND NOMENCLATURE

A	-	Ampere
AC	-	Air cool
AC	-	Alternative current
CAD	-	Computer Aided Design
CAM	-	Computer Aided Manufacturing
CNC	-	Computer Numerical Controller
DC	-	Direct Current
DMD	-	Direct Metal Deposition
EDX	-	Electron Dispersion X-Ray
FCC	-	Face Centred cubic
HAZ	-	Heat affected zone
HRC	-	Rockwell hardness
HV	-	Vickers hardness
PWHT	-	Post weld heat treatment
SEM	-	Scanning Electron Microscope
TIG /GMAW	-	Tungsten inert gas
UTS	-	Ultimate tensile strength
VP	-	Variable polarity
WQ	-	Work cool
YS	-	Yield stress
Al	-	Aluminium
B	-	Boron
Co	-	Cobalt
Fe	-	Ferrous
h	-	Hour
HfC	-	Hafnium carbide
Ni	-	Nickel
Nb	-	Niobium

Ti	-	Titanium
Zr	-	Zirconium
3D	-	Three dimensional
Al_2O_3	-	Aluminium oxide
Cr_2O_3	-	Chromium (III) oxide
CO_2	-	Carbon dioxide
M_6C	-	Carbide rich in W(tungsten) and Molybdenum
$M_{23}C_6$	-	Chromium rich carbides
$Ni_3(Al,Ti)$	-	Nickel Aluminide (Ni_3Al)
Li_2	-	Primitive cubic
γ	-	Gamma matrix
γ'	-	Gamma prime
γ''	-	Gamma double prime
μ	-	Micron

CHAPTER 1
INTRODUCTION

This chapter introduces the background of the nickel-based alloy which has been deposited layer by layer using the direct metal deposition tungsten inert gas welding and the mechanical properties after the heat treatment process. The project's objectives, scope and the problem statement is provided. The work planning and instruction also has been discussed in this chapter and thus the overview of this project has been outlined.

1.1 Background

Direct metal deposition is the process that use the application almost same as the welding process that occur now. It use the high power laser, plasma arc, electron beam and electric arc as the source to melt the powdered and wire metal and making a deposited layer by layer to form a three dimensional product. This process can fully fabricated the parts directly from the CAD data. Today, this process has been widely used in the industrial application such as aerospace and aircraft repair, thermal management and many more. The materials that can be used in the deposition process are such as metal powder, nickel superalloys, and matrix composite material.

The study on the reparability and surface deposition by tungsten inert gas (TIG) process on Waspaloy has been made by Gregori and Bertaso (2004). From the study, Gregori and Bertaso (2004) has state that the weld metal and HAZ hardness of the material almost completely recovered after the heat treatment of deposited Waspaloy and the γ'-phase re-formed in the HAZ during the heat treatment.

In this study, the material that has been use to undergo this layer by layer deposition process is nickel-based alloy. This material is the most complex among all of the superalloy and has the high phase stability of face-centered cubic (FCC) nickel matrix and the capability to strengthen by a variety of direct and indirect means. The microstructure of nickel-base alloy are consists in different phases which are gamma phase, denoted γ, gamma prime precipitate, denoted γ' and carbides and borides (Smith, 1993). A typical type of the nickel based alloy used is Waspaloy. Waspaloy is one of the nickel base alloys with an excellent high temperature strength and good corrosion to resistance, notably to oxidation, and for critical rotating application.

The layer by layer deposition process can form or produce inhomogeneous material of the deposited Waspaloy due to the dynamic heat distribution during the process. Heat treatment is one of the alternative ways to alter the material properties. The carbide formation at the grain boundary during the deposit Waspaloy also will affect the mechanical properties of the material. Thus, the carbide formation and types of grain boundary distribution of the material can be control by the heat treatment procedure.

1.2 Problem Statement

Layer by layer deposited process is one of the process that applying the metal powder and wire onto the improper surface or also can be describe as one of the repairing process for the uneven product beside can produce the three dimensional product from the CAD data. There are several of materials that can be used in this process but the material that use in this study is Waspaloy. This material has its own properties and can affect the mechanical properties of the part produce. The layer by layer deposited Waspaloy by using TIG welding will produce the inhomogenous structure due to the dynamic heat distribution during the process. This inhomogenous structure is difficult to determine its actual melting point, thus the structure should be in homogeneous. To obtain the homogenous structure, the heat treatment will be applied on the deposited Waspaloy. Different heat treatments that apply to the material can bring to the different mechanical properties and microstructure of the deposited Waspaloy. So, in this study, the affect of different heat treatment conditions on the material properties of the deposited Waspaloy will be investigated.

The different temperature and time that use on the heat treatment process also will cause the changing of the microstructure of the deposited Waspaloy thus also contribute towards the changing in its mechanical properties. So, the effect of the temperature and time towards the microstructure is determined by using the Optical Microscope. From the microscope, the difference of the microstructure and its arrangement of the treated deposited material can be figure out.

However, the types of grain boundary that form from the deposited Waspaloy also are a critical situation because it can affect the mechanical properties of the material. The discrete type of carbide should be obtained to ensure that the deposited Waspaloy has the high mechanical properties that can resist fracture rather than the continuous carbide formation (film). So, the types of boundary formation in the deposited layer of Waspaloy need to be determined.

1.3 Objectives

- To determine the effect of different temperature and time that can affect the microstructure of deposited Nickel-based alloy.
- To study the effect of heat treatment condition on the hardness properties of deposited Nickel-base alloy.
- To suggest the optimum heat treatment condition that can gives the homogeneous material properties and desire types of grain boundaries formation of deposited Nickel-based alloy.

1.4 Scopes

This study will focus on the deposited Waspaloy after the various heat treatments. The mechanical properties of the deposited Waspaloy for each specimen are determined by using the microhardness testing machine. The strength and the hardness will be figure out from this process. For the microstructure and types of boundary formation of the deposited Waspaloy, the microstructure can be captured by using the optical microscope. From the microstructure that has been obtain, the further study of the different heat treatment can be introduce to obtain more detail information of the deposited Waspaloy.

1.5 Work Planning

The planning for this Final Year Project (FYP) has been listed in the table below. The Gantt chart has been attached together and can be referred at Appendix A and Appendix B.

Table 1.1: Work Planning for FYP 1.

NO	WEEK	TASK
1	1	Consultant and first meeting with supervisor to discuss about the selected topic.
2	1-15	Gather the information for the literature review
3	3-6	Completion of Chapter 2
4	6-8	Preparation and completion of Chapter 1
5	8-10	Explore info for Chapter 3 and survey equipment for lab
6	10-11	Experiment planning and conduct experiment testing
7	11-12	Submission and edit Draft Report
8	12-13	Amalgamation of three chapters and completion of PSM 1
9	13	Finalize and submission of report
10	14	Preparation of FYP 1 presentation
11	15	FYP 1 Presentation

Table 1.2: Work Planning for FYP 2.

No	Week	Task
1	1	Preparation for the experiment
2	2-3	Experiment implementation
3	3-7	Testing stage for specimen
4	6-8	Further testing for data accuracy
5	7-9	Analyzed and discuss on the experiment results
6	9-11	Completion of chapter four
7	11-12	Completion of chapter five
8	12-13	Completion of full report
9	14	Edit and correct the draft of full report
10	15	Submission of full report (Comb binding)
11	15-16	Presentation for FYP presentation
12	16	FYP presentation
13	17-19	Submission of full report (Hard bound)

1.6 Summary

The overview of the study is described followed by the problem statement. From the problem statement that has been figured out, a list of objectives were carried out to solve the problem. For successfully carried out the study, scope of the study was determine further by the work planning schedule.