



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

FLORENCE KUEH HUI NA

B050810225

880922135218

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- TIDAK TERHAD

Alamat Tetap:

Lot 1790, Taman Desa Senadin,

Phase 1, Lutong Kuala Baram,

Miri, Sarawak

Tarikh: 29 JUNE 2012

Disahkan oleh:

Cop Rasmi:

DR. NUR IZAN SYAHRIAH BINTI HUSSEIN
Head Of Department (Manufacturing Process)
Faculty of Manufacturing Engineering
Universiti Teknikal Malaysia Melaka

Tarikh: 27/6/2012

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Signature :

Author's Name : Florence Kueh Hui Na

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 kenaikan 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 inhomogeneous 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 Waspaloy 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 optimum heat treatment temperature were similar to the standard heat treatment that apply for wrought Waspaloy which is solution treatment 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.

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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 Izzah 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.

TABLE OF CONTENT

Abstrak	i
Abstract	ii
Dedication	iii
Acknowledgement	iv
Table of Content	v
List of Tables	ix
List of Figures	x
List Abbreviations, Symbols and Nomenclature	xiv
CHAPTER 1 : INTRODUCTION	1
1.1 Background	1
1.2 Problem Statement	2
1.3 Objectives	3
1.4 Scopes	4
1.5 Work planning	4
1.6 Summary	5
CHAPTER 2 : LITERATURE REVIEW	6
2.1 Introduction	6
2.2 Welding	6
2.2.1 Types of Welding	7
2.2.2 Fusion Welding	7
2.2.3 Heat Source in Welding	8
2.2.4 Tungsten Inert Gas (TIG) Welding	8
2.2.4.1 Electric Arc	9
2.2.4.2 Material	10
2.2.4.3 Application	10
2.3 Direct Metal Deposition	11
2.3.1 Process DMD	12

2.3.2	Heat Source	13
2.3.3	Material	13
2.3.4	Process Parameter	13
2.3.5	Advantages of DMD	13
2.4	Superalloy	14
2.4.1	Nickel-Based Alloy	15
2.4.1.1	Chemical Composition	15
2.4.1.2	Microstructure	16
2.5	Heat Treatment	20
2.5.1	Solution Treatment	20
2.5.2	Quenching	21
2.5.3	Ageing Treatment	21
2.6	Waspaloy	22
2.6.1	Wrought Waspaloy	22
2.6.1.1	Chemical Composition	23
2.6.1.2	Microstructure	23
2.6.1.3	Physical Properties	23
2.6.1.4	Mechanical Properties	24
2.6.1.5	Heat Treated of Wrought Waspaloy	25
2.6.2	Welded Waspaloy	30
2.6.2.1	Chemical Composition	31
2.6.2.2	Microstructure	31
2.6.2.3	Mechanical Properties	32
2.6.2.4	Heat Treated Welded Waspaloy	33
2.6.3	Deposited Waspaloy	34
2.6.3.1	Microstructure	34
2.6.3.2	Mechanical Properties	35
2.6.3.3	Heat Treated Deposited Waspaloy	36
2.7	Summary	38
CHAPTER 3: METHODOLOGY		39
3.1	Flowchart	39
3.1.1	Design for Final Year Project 1 (FYP 1)	41

3.1.1.1	Information Preparation	41
3.1.1.2	Conceptualization	41
3.1.1.3	Methodology Design	43
3.1.2	Design for Final Year Project 2 (FYP 2)	43
3.1.2.1	Flow Chart for FYP2	43
3.1.2.2	Observation	44
3.1.2.3	Analysis	45
3.1.2.4	Concluding	45
3.2	Experiment Procedure	45
3.2.1	Sample Preparation (before heat treatment)	46
3.2.2	Heat Treatment	46
3.2.3	Sample Preparation (after heat treatment)	48
3.2.3.1	Mounting	48
3.2.3.2	Grinding	49
3.2.3.3	Polishing	50
3.2.3.4	Etching	50
3.2.4	Microstructure Analysis	51
3.2.4.1	Optical Microscope	51
3.2.5	Mechanical Testing	51
3.2.5.1	Sample Preparation	52
3.2.5.2	Microhardness Test (Vickers)	52
3.3	Result Recording	53
3.4	Summary	54
CHAPTER 4: RESULT & DISCUSSION		55
4.1	Result	55
4.1.1	Microstructure Analysis	55
4.1.1.1	Microstructure Analysis As-received Waspaloy	56
4.1.1.2	Microstructure Analysis of Deposited Waspaloy	59
4.1.1.3	Microstructure Analysis of Deposited Waspaloy with Solution Treatment	59
4.1.1.4	Microstructure Analysis of Deposited Waspaloy with Solution Treatment followed by	

	Stabilization and Ageing Process at 760°C for 16 hour	61
4.1.1.5	Microstructure Analysis of Deposited Waspaloy with Solution Treatment followed by Stabilization and Ageing Process at 760C for 30 hour	65
4.1.2	Microhardness Analysis	67
4.1.2.1	Microhardness test for As-received Waspaloy	67
4.1.2.2	Microhardness test for Deposited Waspaloy	67
4.2	Discussion	70
4.2.1	Microstructure Analysis	70
4.2.2	Hardness Variation from Various Heat Treatment Procedure	73
4.2.3	Summary	76
	CHAPTER 5: CONCLUSION & FUTURE WORK	77
5.1	Conclusion	77
5.2	Recommendation	79
	REFERENCES	80
	APPENDICES	
A	Gantt Chart for Final Year Report 1 (FYP 1)	
B	Gantt Chart for Final Year Report 2 (FYP 2)	

LIST OF TABLES

1.1	Work Planning for FYP 1	4
1.2	Work Planning for FYP 2	5
2.1	Major types and example of Fusion Welding	8
2.2	Nominal composition % of wrought Waspaloy	23
2.3	Physical properties of Waspaloy	24
2.4	Microstructure of Waspaloy in the wrought and forged condition after elevated temperature exposure	24
2.5	Typical solution treating and aging cycle for wrought Waspaloy	25
2.6	Nominal composition % of welded (cast) Waspaloy	31
2.7	Hardness of deposited Waspaloy with different current	36
2.10	Hardness of deposited Waspaloy after post weld heat treatment with different current	38
3.1	Heat treatment procedure for each specimen	47
3.2	Example table for microhardness test data record	53
4.1	Microhardness result for As-received Waspaloy, As-received with solution treatment and As-received with solution treatment followed by stabilization and aging process.	68
4.2	(a) Microhardness data for heat treated deposited Waspaloy	68
	(b) Microhardness data for heat treated deposited Waspaloy (continue)	69

LIST OF FIGURES

2.1	Illustration of the TIG welding	10
2.2	Illustration of Direct Metal Deposition, DMD with close loop system	11
2.3	Five common methodologies apply in DMD	12
2.4	Alloying elements use in Nickel-based superalloys	16
2.5	The unit cell of face-centred cubic (FCC) crystal structure, line sketches (left) and hard sphere atomic model (right) display by nickel	17
2.6	Line sketch of an ordered FCC crystal structure of γ' phase	18
2.7	Carbides in microstructure of nickel-based superalloys (original magnification (a)= 2000x (b)= 3000x (c)=5000x (d)=20,000x	19
2.8	Wrought Waspaloy showing spheroidal nature of early (low $v_f \gamma'$)	23
2.9	Standard heat treatment chart for Waspaloy	26
2.10a	Microstructure of Waspaloy after heat treatment, close surface (TEM DF image)	27
2.10b	Microstructure of Waspaloy after heat treatment, in centre of billet (TEM DF image)	27
2.11	Microstructure of Waspaloy strengthen by γ' heat treated 1010°C, 4h oil quenched plus 843°C, 4h, air cool plus 760°C 16h, air cool	28
2.12	Effect of heat treatment on γ' size in Waspaloy, (a) fine γ' and (b) bimodal γ'	28
2.13	Vickers microhardness of aging time for Waspaloy specimen heat treated at 600, 725, 800 and 875°C. value located at 0.01h represent the solution treated specimen	30
2.14	Light photomicrograph show HAZ of single pass bead on plate by using Waspaloy filler wire and pulsed AC TIG	31
2.15	Light photomicrograph of single pass bead on plate by using Waspaloy filler wire and pulsed AC TIG	32
2.16	The hardness profiles of the bead welded in an as-annealed	33

	Waspaloy sheet, showing the hardness peaks of the fusion zone and the heat-affected zone boundaries	
2.17	Light photomicrograph showing typical HAZ 6 pass build up of deposited Waspaloy filler wire by using TIG and liquation of grain boundaries carbides	35
2.18	Light photomicrograph 6 pass build up of deposited Waspaloy filler wire by using VP TIG	35
2.19	SEM of deposited Waspaloy by TIG and forced cool HAZ after post weld heat treatment	36
2.20	Light photomicrograph of heat treated deposited Waspaloy	37
3.1	Overall flowchart for Final Year Project	40
3.2	Sequence in Final Year Project 1	42
3.3	Sequence in Final Year Project 2	44
3.4	Abrasive cutter	46
3.5	Furnace for Heat treatment	47
3.6	Sample after heat treatment procedure	48
3.7	Automatic press machine for mounting process	49
3.8	Specimen after mounting process	49
3.9	Polishing machine	50
3.10	Optical microscope	51
3.11	Mitutoyo microhardness testing machine (Vickers)	52
4.1a	Representative optical micrograph of grain structure of As-received Waspaloy	56
4.1b	Representative optical micrograph of grain structure of As-received Waspaloy with solution treatment at 1080°C for 4 hour	57
4.1c	Representative optical micrograph of grain structure of As-received Waspaloy with solution treatment at 1080°C for 4 hour followed by stabilization at 845°C for 4 hour and aging process at 760°C for 16 hour	57
4.2	Further magnification towards grain boundary of A	58
4.3	Optical micrograph of the further magnification 100× of grain	58

	boundary for (a) solution treatment of 1080°C and (b) solution treatment at 1080°C for 4 hour followed by stabilization at 845°C for 4 hour and aging process at 760°C for 16 hour	
4.4	Optical micrograph of as-received deposited Waspaloy	59
4.5	Optical micrograph of deposited Waspaloy with solution treatment (a) 1080°C for 4 hour (3D), (b) 995°C for 4 hour (9D), (c) 1080°C for 25 hour (15D) and (d) 995°C for 25 hour (21D)	60
4.6	Optical micrograph of deposited Waspaloy at grain boundary with solution treatment (a) 1080°C for 4 hour, (b) 995°C for 4 hour, (c) 1080°C for 25 hour and (d) 995°C for 25 hour	60
4.7	Microstructural for ageing at 760°C for 16 hour. (a) and (b) Solution treatment at 1080°C for 4 hour and stabilization at 845°C for 4 hour (4D). (c) and (d) Solution treatment at 1080°C for 4 hour and stabilization at 845°C for 8 hour (5D)	61
4.8	Microstructural for aging at 760°C for 16 hour. (a) and (b) Solution treatment at 995°C for 4 hour and stabilization at 845°C for 4 hour (10D). (c) and (d) Solution treatment at 995°C for 4 hour and stabilization at 845°C for 8 hour (11D)	62
4.9	Microstructural for aging at 760°C for 16 hour. (a) and (b) Solution treatment at 1080°C for 25 hour and stabilization at 845°C for 4 hour. (c) and (d) Solution treatment at 1080°C for 25 hour and stabilization at 845°C for 8 hour	63
4.10	Microstructure for aging at 760°C for 16 hour. (a) and (b) Solution treatment at 995°C for 25 hour and stabilization at 845°C for 4 hour. (c) and (d) Solution treatment at 995°C for 25 hour and stabilization at 845°C for 8 hour	64
4.11a	Optical micrograph of (a) and (b) 1080°C for 4 hour followed by double ageing process at 845°C for 16 hour and 760°C for 30 hours (c) and (d) 1080°C for 25 hour followed by double ageing process at 845°C for 16 hour and 760°C for 30 hour	65
4.11b	Optical micrograph for (e) and (d) 995°C for 4 hour followed by double ageing process at 845°C for 16 hour and 760°C for 30 hours (g) and (h) 995°C for 25 hour followed by double ageing process at	66

	845°C for 16 hour and 760°C for 30 hours	
4.12	Vickers microhardness for wrought Waspaloy with different heat treatment	73
4.13	Vickers microhardness for deposited Waspaloy with various heat treatment procedures	74

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 ₂ O ₃	- Aluminium oxide
Cr ₂ O ₃	- Chromium (III) oxide
CO ₂	- Carbon dioxide
M ₆ C	- Carbide rich in W(tungsten) and Molybdenum
M ₂₃ C ₆	- Chromium rich carbides
Ni ₃ (Al,Ti)	- Nickel Aluminide (Ni ₃ Al)
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 used 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 consists of 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 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 controlled by the heat treatment procedure.

1.2 Problem Statement

Layer by layer deposited process is one of the processes that apply the metal powder and wire onto the improper surface or also can be described as one of the repairing processes for the uneven product. Besides, it can produce three-dimensional products from CAD data. There are several materials that can be used in this process, but the material used in this study is Waspaloy. This material has its own properties and can affect the mechanical properties of the part produced. The layer by layer deposited Waspaloy by using TIG welding will produce an inhomogeneous structure due to the dynamic heat distribution during the process. This inhomogeneous structure is difficult to determine its actual melting point, thus the structure should be homogeneous. To obtain a homogeneous structure, 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.