UNIVERSITI TEKNIKAL MALAYSIA MELAKA

STUDY AND MEASUREMENT OF CUTTING TOOL COATING THICKNESS BY USING BETA THICKNESS GAUGING METHOD

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

By

MOHD HILAL BIN ABDUL AZIZ (B050710248)

Supervisor:

MR. MOHD FAIRUZ BIN DIMIN

Faculty of Manufacturing Engineering

2010

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PSM

JUDUL: **STUDY AND MEASUREMENT OF CUTTING TOOL COATING THICKNESS BY USING BETA THICKNESS GAUGING METHOD**

SESI PENGAJIAN: **SEMESTER 2 (2009-2010)**

Saya **MOHD HILAL BIN ABDUL AZIZ**

mengaku membenarkan laporan PSM / tesis (PSM/Sarjana/Doktor Falsafah) ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Laporan PSM / tesis adalah hak milik Universiti Teknikal Malaysia Melaka.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan laporan PSM / tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (/)

☐	SULIT	(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia yang termaktub di dalam AKTA RAHSIA RASMI 1972)
☐	TERHAD	(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)
☑	TIDAK TERHAD	

Disahkan oleh:

(PELAJAR)

(PENYELIA PROJEK)

Alamat Tetap:
No.10, Kg. Guru, Batu 30,
Jalan Taiping, 34100 Selama,
Perak Darul Ridzuan.

Tarikh: 25 Mei 2010

Cop Rasmi:
MOHD FAIRUZ DIMIN
PENSYARAH
JABATAN PROSES PEMBUATAN
FAKULTI KEJURUTERAAN PEMBUATAN
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Tarikh: 25 Mei 2010

* Jika laporan PSM ini SULIT atau TERHAD, sila lampirkan surat daripada pihak organisasi berkenaan dengan menyatakan sekali sebab dan tempoh tesis ini perlu dikelaskan sebagai SULIT atau TERHAD.

DECLARATION

I hereby, declared this thesis entitled "Study and Measurement of Cutting Tool Coating Thickness by Using Beta Thickness Gauging Method" is the results of my own research except as cited in references.

Signature	:	………………………………………………
Author's Name	:	MOHD HILAL BIN ABDUL AZIZ
Date	:	25 MAY 2010

APPROVAL

This PSM submitted to the senate of UteM and has been as partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Process Manufacturing) with Honours. The members of the supervisory commitee are as follows:

....

(MR. MOHD FAIRUZ BIN DIMIN)

PSM Supervisor

ABSTRACT

There are many types of methods in measuring the coating thickness. One of the methods is by using Beta Thickness Gauging method. The purpose of this study is to determine the thickness of cutting tool coating by using the beta (β) backscattering gauging technique. The intensity of the backscattered beta particle radiations of Srontium-90 (Sr-90) and Cobalt-60 (Co-60) is related to the thickness of material coating on the base material of cutting tool. With a fixed measuring geometry, the radioactive sources and base material, the intensity of backscattered beta particle is dependent on the coating thickness. The results were compared with the methods and sources of thickness measurement. There are several parameters that involved in this measuring process, such as thickness, angle of source holder and source detector over the surface, distance between specimen and source, and other. Value of cutting tool coating thickness is measured by using GM (Geiger-Müller) counter instrument that can detect a single particle of ionizing radiation, and also by using backscattering technique.

ABSTRAK

Terdapat pelbagai jenis kaedah yang digunakan dalam mengukur ketebalan lapisan saduran. Salah satu daripadanya ialah dengan menggunakan kaedah pengukur ketebalan beta (β). Tujuan eksperimen dan pembelajaran ini adalah untuk menentukan ketebalan lapisan saduran pada mata alat dengan menggunakan teknik pengukuran sebar-balik beta (β). Dalam pengamatan mengenai penyebaran-balik zarah-zarah radiasi beta (β) dari Srontium-90 (Sr-90) dan Cobalt-60 (Co-60) adalah berkaitan dengan ketebalan bahan saduran yang digunakan pada bahan asas mata alat. Dengan penetapan geometri pengukuran, sumber-sumber radioaktif, dan bahan asas, pengamatan dari penyebaran-balik zarah beta (β) adalah bergantung pada ketebalan saduran. Keputusan yang diperolehi dibandingkan dengan kaedah-kaedah dan sumber-sumber pengukuran ketebalan yang digunakan. Terdapat beberapa parameter yang terlibat dalam proses pengukuran ini seperti ketebalan, sudut pemegang sumber dan pengesan sumber ke atas permukaan, jarak antara spesimen dan sumber, dan sebagainya. Nilai ketebalan saduran pada mata alat adalah diukur dengan menggunakan alat pengira GM (Geiger-Müller) yang boleh mengesan zarah dari ion-ion radiasi dan juga dengan menggunakan teknik penyebaran-balik.

DEDICATION

For my family, lecturers, and friends

ACKNOWLEDGEMENT

Firstly, I would like to acknowledge and express my gratitude and appreciation to my supervisor, En. Mohd Fairuz Bin Dimin for his supervision, encouragement, suggestion, advice and support. An appreciation too for my parents Abdul Aziz Bin Mohd Nasir and Nor Aziyah Binti Mohd Shohor whose give a constant encouragement, faith, confidence, and continuously of moral support.

It is a pleasure for me to express huge gratitude to all individuals and colleagues which have contribute so much throughout my study and give commitment during this research. Not forget to my friends and other people that are not listed in fulfilling this research, whereas their advice and assistance in various ways was extremely helpful. I could offer here only an inadequate gesture of my appreciation and all of your good deeds will always be in my mind.

Thank you so much…

TABLES OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

Am-241	-	Americium-241
AFM	-	Atomic Force Microscope
Co-60	-	Cobalt-60
CrN	-	Chromium Nitride
CrTiAlN	-	Chromium Titanium Aluminium Nitride
CVD	-	Chemical Vapor Deposition
ERDA	-	Elastic Recoil Detection Analysis
eV	-	Electron Volt
FEM	-	Finite Elements Method
GDOES	-	Glow Discharge Optical Emission Spectroscopy
GM	-	Geiger-Müller
HERDA	-	Heavy-Ion Elastic Recoil Detection Analysis
IRE	-	Internal Reflection Element
kBq	-	Kilo-Becquerel
LIBS	-	Laser-Induced Breakdown Spectroscopy
PES	-	Proton Enhanced Scattering
PIXE	-	Proton Induced X-ray Emission
PSM	-	Projek Sarjana Muda
PVD	-	Physical Vapor Deposition
RBS	-	Rutherford Backscattering
RCVD	-	Reactive Chemical Vapor Deposition
Sr-90	-	Srontium-90
TiAlN	-	Titanium Aluminium Nitride
TiN	-	Titanium Nitride
UTeM	-	Universiti Teknikal Malaysia Melaka
UV	-	Ultraviolet
XPS	-	X-ray Photoelectron Spectroscopy

CHAPTER 1

INTRODUCTION

1.1 Background

The selection of cutting tool materials for a particular application is among the most important factors in machining operations, as is the selection of mold and die materials for forming and shaping processes. As noted in engineering technology, the cutting tool is subjected to several factors such as high temperatures, high contact stresses, and rubbing along the tool-chip interface and along the machined surface. Consequently, the cutting tool material must possess the criteria such as hot hardness, toughness and impact strength, thermal shock resistance, wear resistance and chemical stability. To respond to these demanding requirements, various cutting tool materials with a wide range of mechanical, physical, and chemical properties have been developed over the years.

Tool materials generally are divided into the several categories, listed in the order in which they were developed and implemented in industry. There are many of these materials also are used for dies and molds in casting, forming, and shaping metallic and non-metallic materials. The types of cutting tool are such as high-speed steels, cast-cobalt alloys, carbides, coated tools, alumina-based ceramics, cubic boron nitride, silicon-nitride-based ceramics, diamond, and whisker-reinforced materials. However, the difficulty of machining these materials efficiently and the need for improving the performance in machining the more common engineering materials have led to important developments in coated tools.

The aim of applying coatings is to improve surface properties of a bulk material usually referred to as a substrate. Coatings have unique properties, such as lower friction, higher adhesion, higher resistance to wear and cracking, acting as a diffusion barrier, and higher hot hardness and impact resistance. Coated tools can have tool lives 10 times longer than those of uncoated tools, allowing for high cutting speeds and thus reducing both the time required for machining operations and production costs. As a result of widely usage, coated tools now are used in 40 to 80% of all machining operations, particularly in turning, milling, and drilling. Surveys have indicated that the use of coated tools is more prevalent in large companies than in smaller ones (David Beamish, 2001).

Commonly used as coating materials are titanium nitride (TiN), titanium carbide (TiC), titanium carbonitride (TiCN), and aluminum oxide (Al_2O_3). These coatings, generally in the thickness range of 2 to 15 µm, are applied on cutting tools and inserts by two techniques. The first technique is Chemical-vapor Deposition (CVD), including plasma-assisted chemical-vapor deposition and the second one is Physical-vapor Deposition (PVD). The CVD process is the most commonly used method for carbide tools with multiphase and ceramic coatings. The PVD-coated carbides with TiN coatings, on other hand, have higher cutting edge strength, lower friction, lower tendency to form a built-up edge, and are smoother and more uniform in thickness, which is generally in the range of 2 to 4 µm (Hiroaki Yamamoto, 1996).

Coatings for cutting tools and dies should have the following generally characteristics, that are high hardness at elevated temperatures to resist wear. Besides that, it must have a chemical stability and inertness to the workpiece material in purpose to reduce wear. Other characteristic is it must compatibility and has good bonding to the substrate to prevent flaking or spalling. It is also must little or no porosity in the coating to maintain its integrity and strength. The effectiveness of coatings is enhanced by the hardness, toughness, and high thermal conductivity of the substrate (which may be carbide or high-speed steel). Honing of the cutting edges is an important procedure for the maintenance of coating strength; otherwise, the coating may peel or chip off at sharp edges and corners (Andrew J. Slifka, 1999).

Coatings can be measured and tested for proper opacity and film thickness by using several of methods or techniques. The evaluation of coatings is an important part of the quality assurance process in many industries. It also enables the optimum use of material. A prerequisite for this is that coating thicknesses can be accurately measured. Of course this applies not only to coatings on metal parts but also to such coatings on base materials like wood, plastics, ceramic, glass, and others. Until now, sample analysis of unknown bulk material alloys or unidentified coatings has required certain knowledge of what to expect before accurate quantitative results could be obtained (Edgar Gutoff, 2001).

A variety of recognized methods can be used to determine the thickness of organic coatings. The method employed in a specific situation is most often determined by the type of coating and substrate, the thickness range of the coating, the size and shape of the part, and economics. Commonly used measuring techniques are nondestructive dry film methods such as magnetic, eddy current, ultrasonic or micrometer measurement; destructive dry-film methods such as cross-sectioning or gravimetric (mass) measurement; and wet-film measurement. However, in this PSM project, the technique or method that will be use is beta (β) thickness gauging method. The purpose of this project and research is to determine the thickness of cutting tool coating by using this kind of method, whereas it was using beta radiation as its source.

In this method, the process that happened is direct which the cutting tool is placed on the part to be measured and the radiation source will be used to detect it. When the cutting tool is positioned, the linear distance between the cutting tool and detector contacts the surface and the base substrate is measured. There are a few of parameters that involves in this measuring process, such as thickness, angle of source holder and source detector over the surface, distance between specimen and source, and so on. Value of cutting tool coating thickness is measured by using GM (Geiger- Müller) counter instruments.

1.2 Problems Statement

The problems statement is to study the feasibility or practicability of beta (β) backscatter thickness measurement and measuring technique of tool machining. The advantage of this technique is measuring the cutting tool coating thickness in situ and no destruction of the tool to be measured.

1.3 Objectives of Project

The purposes of this project are:

i. To develop a method of measuring the coating thickness of cutting tool by using beta (β) gauging technique.

ii. To measure the cutting tool coating thickness by using backscattering technique from different type of beta radiation source.

iii. To compare the accuracy of coating thickness obtains from different beta source material and the conventional method.

1.4 Scope of Project

This research is about to study and determine the coating thickness of cutting tool, which was measured by using beta (β) thickness gauging method. Samples of cutting tool base material of sintered tungsten carbide coated with titanium aluminium nitride was prepared using the physical vapor deposition machine available in the Advance Manufacturing Centre, UTeM. The control variables in this measuring process are angle of source holder and distance between specimen and source. Value of cutting tool coating thickness was measured by using beta (β) scattering technique where the GM (Geiger-Muller) counter and the GM tube are used to measure the reflected Beta particle from the target material.

1.5 Report Outline

This report writing consists of three chapters for Projek Sarjana Muda (PSM) 1. Chapter 1 is describes about introduction; which is includes the project background, problem statement, objective of project, scope of project, and the importance of this study. Then the Chapter 2 stressed on the literature review of related issues and for Chapter 3, it was highlighted more towards the methodology of the project, which is includes the process planning for this project, flowchart, data gathering method, and analytical techniques in this project.

For the next phase of Projek Sarjana Muda, which is in PSM 2, it was covered with three more chapters. Chapter 4 is about the result and analysis of experimental that have been done, while Chapter 5 is contents discussion by referring the whole processes and results. Lastly in Chapter 6, it had state the conclusion and recommendation to improve the experimental or analysis of this project in the next time.

1.6 Gantt Chart of PSM

Below Gantt chart shows the planning and actual process in this project. Not all of the plans work properly as planned because of some technical problems.

Project Planning																		
Major Activities Involved in Project Sarjana Muda 1 (2009)																		
Project Activity / Week		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
Choose and understand the project that have been suggested	Planning																	
	Actual																	
Get advices from supervisor	Planning																	
	Actual																	
Collect information and related theory	Planning																	
	Actual																	
Chapter 1 finish	Planning																	
	Actual																	
Chapter 2 finish	Planning																	
	Actual																	
Chapter 3 finish	Planning																	
	Actual																	
Prepare final report	Planning																	
	Actual																	
PSM 1 presentation	Planning																	
	Actual																	

Table 1.1: Gantt chart of PSM 1 activities

Project Planning																		
Major Activities Involved in Project Sarjana Muda 2 (2010)																		
Project Activity / Week		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
Search for journals and books	Planning	■	■															
	Actual	■	■															
Discuss and get advices from supervisor	Planning	■	■	■	■	■	■			■	■	■	■		■	■	■	■
	Actual	■	■	■	■	■	■	■		■	■	■	■		■	■	■	■
An experimentally about this study and research	Planning			■	■	■	■	■	■	■	■	■	■					
	Actual			■	■	■	■	■	■	■	■	■	■	■				
Chapter 4 finish	Planning				■	■	■											
	Actual				■	■	■	■	■									
Chapter 5 finish	Planning							■	■	■								
	Actual							■	■	■	■	■						
Chapter 6 finish	Planning										■	■	■					
	Actual										■	■	■	■				
Prepare final report	Planning							■	■	■	■	■	■	■	■			
	Actual								■	■	■	■	■	■	■	■		
PSM 2 presentation	Planning																	■
	Actual																	■

Table 1.2: Gantt chart of PSM 2 activities

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Coatings perform a variety of important functions including protecting and beautifying outdoor structures and manufactures goods. Accurately measuring the thickness of these coatings helps maintain product quality and control production costs. Several types of instruments are available to measure coatings in their uncured (wet) or cured (dry) state. Proper instrument selection is crucial to obtaining accurate, meaningful results. Instrument selection is dependent upon the type and thickness range of the coating, the substrate material, the shape of the part, and the need for statistical analysis. To make this choice, one must understand the different for coating thickness measurement. Below are attachments of journals in experimental about how the parameters are selected and the processes to determine the feasibility and practicability of this research.

2.2 Measurement of Coating Thicknesses

Hironori and Manabu did an experiment in measuring the coating thickness on the back side of double sided coated structures by means of acoustic resonant spectroscopy. It is describes a technique for measuring the thickness of the back side coating of a double-sided coated structure using acoustic resonance. The technique is used to observe the resonant frequency of high frequency ultrasound for a steel/coating/air structure. The resonant frequency of the transmitted ultrasound occurs when a quarter wavelengths correspond to the thickness of the back side coating, and the reflection coefficient has a minimum value. The top surfaces of the samples are covered with a coating about 30 μm thick and the thickness of the back side coating is in the range of 10.3 – 17.5 μm. The resonant frequencies for the examined samples are observed in the frequency range of 46.8 – 75.6 MHz, and the thickness of the back side coating can be accurately determined from the measured resonant frequency. The coating on the top surface of the structure does not affect the thickness measurement accuracy of the back side coating (Hironori Tohmyoh, Manabu Suzuki, 2009).

In measuring the thickness of protective coatings on historic metal objects using nanosecond and femtosecond laser induced breakdown spectroscopy depth profiling, it is show that the depth profile analysis by means of laser induced breakdown spectroscopy (LIBS) was investigated with respect to its potential to measure the thickness of different types of thin organic films used as protective coatings on historical and archaeological metal objects. For the materials examined, acrylic varnish and microcrystalline wax, the output from a nanosecond ArF excimer laser at 193 nm was found appropriate for performing a reliable profiling of the coating films leading to accurate determination of the coating thickness on the basis of the number of laser pulses required to penetrate the coating and on the ablation etch rate of the corresponding coating material under the same irradiation conditions. Nanosecond pulses at 248 nm proved inadequate to profile the coatings because of their weak absorption at the laser wavelength. In contrast, femtosecond irradiation at 248 nm yielded well-resolved profiles as a result of efficient ablation achieved through the increased non-linear absorption induced by the high power density of the ultrashort pulses (P. Pouli, K. Melessanaki, A. Giakoumaki, V. Argyropoulos, D. Anglos, 2005).

For the determination of the coating thicknesses due to the scattered radiation in energy dispersive x-ray fluorescence spectrometry, a method is presented to determine the coating thickness on a metallic substrate in energy dispersive X-ray fluorescence. The method is based on the measurement of incoherent scattered radiation. The energy dispersive XRF apparatus includes a filtered Am^{241} point source and a Si (Li) detector with resolution 160 eV at 5.9 keV. The thicknesses of the coating materials found by the scattered radiation have been compared with thicknesses found by the gravimetric method. The obtained results show that there is good agreement between the present experimental results and the values of the gravimetric method within the estimated experimental error (N. Ekinci, Y. Kurucu, E. Öz, Y. Sahin, 2002).

Measuring film thickness using infrared imaging show that an Infrared imaging was used to measure the thickness of a Krylon® flat black spray paint coating applied to the surface of steel test coupons. Thermal signals were generated in the test samples by applying a cyclic tensile load at various frequencies, which generated a corresponding thermo-elastic temperature change. Since the substrate is a better thermo-elastic generator than the paint, the heat generated in the metal conducts through the paint during each cycle of loading and is easily distinguished from the paint signal. Test samples were prepared with a stepped progression of controlled paint thickness, and infrared images taken using a Delta Therm 1000 IR imaging system. The infrared signal intensity as well as the phase lag relative to the applied loading was directly related to the paint thickness. The experimental results are described well using existing heat conduction models. Though the proposed method was proven using thermoelastic heating, any heat source below the paint can be used to provide the necessary reference signal. Furthermore, the method can also be used for any coating type and is not limited to paint coatings (Carrie A. Decker, Thomas J. Mackin, 2005).

In-line determination of the thickness of UV-cured coatings on polymer films by NIR spectroscopy, the report state the development of a measuring method based on near-infrared (NIR) spectroscopy, which is able to determine the thickness of UV-cured coatings and which can be used for in-line monitoring in technical coating processes. In particular, acrylate coatings, which were applied to transparent polymer films with a typical thickness of 5–35 μm, were investigated. NIR spectra were recorded in transflection mode. Quantitative analysis of the spectral data was carried out with partial least square (PLS) regression. In-line measurements were performed on a pilot-scale roll coating machine at web speeds up to 50 m/min. It was shown that quantitative data with excellent precision (i.e. with a standard deviation lower than ±1 μm) and high time resolution (2.5 spectra/s) can be obtained (Katja Heymann, Gabriele Mirschel, Tom Scherzer, Michael R. Buchmeiser, 2009).

A digital instrument for nondestructive measurements of coating thicknesses by Beta backscattering shows the elements of nondestructive gauging of coatings applied on various metal bases. The intensity of the backscattered beta radiations is related to the thickness of the coating. With a fixed measuring geometry and radioactive sources (^{147}Pm, ^{204}Tl, $^{90}Sr+^{90}Y$) the intensity of the backscattered beta particles is dependent on the following parameters: coating thickness, atomic number of the coating material and of the base, the beta particle energy and the surface finish. It can be used for the measurement of a wide range of coating thicknesses provided that the difference between the coating and the support atomic numbers is at least 20%. Fields of application include electronics, electrotechnique and so on (D. M. Farcasiu, T. Apostolescu, H. Bozdog, E. Badescu, V. Bohm, S. P. Stanescu, A. Jianu, C. Bordeanu, M. V. Cracium, 1992).

The research of online coating thickness measurement and depth profiling of zinc coated sheet steel by laser-induced breakdown spectroscopy state the study of new method for online analysis of the zinc coating of galvanized sheet steel based on laser-induced breakdown spectroscopy (LIBS). The coating is characterized with a series of single laser bursts irradiated on the traversing sheet steel, each on a different sheet steel position. To achieve an ablation depth in the range of the coating thickness of about 10 μm a Nd:YAG laser at 1064 nm in collinear double pulse mode was used. The depth information is obtained by control of the ablation depth by adjusting the burst energy using an external electro-optical attenuator. Concepts for the determination of the coating thickness and the chemical composition are presented. The achieved thickness resolution is estimated to about 400 nm for coating thicknesses of electrolytic galvanized sheet steel in the range of 3.2 to 11.2 μm. In the case of hot-dip galvanized sheet steel information about the depth profile of aluminium can be gained by the new method (H. Balzer, M. Hoehne, V. Sturm, R. Noll, 2005).