UNIVERSITI TEKNIKAL MALAYSIA MELAKA

PRELIMINARY STUDY AND MEASUREMENT OF CUTTING TOOL COATING THICKNESS BY USING ALPHA 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

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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 (Manufacturing Process). The member of the supervisory committee is as follow:

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En. Mohamad Nizam Bin Ayof

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ABSTRACT

Coatings thickness of cutting tool perform a variety of important functions including protecting and improving the performance in machining. Accurately, measuring the thickness of these coatings helps maintain product quality and control production costs. These projects are preliminary study and measure the cutting tool coating thickness by using Alpha Thickness Gauging Method. This project highlights the consideration of effects on the accuracy of measurement when using this method. Radioactive material used in the experiments is Radium-226 and Americium-241, while the coating material to be measured is made of Aluminum Titanium Nitride (TiAIN). There have 10 types of cutting tools that used in different coating thickness to be measured. Measurement readings are displayed on the Gieger Muller Counter which records the number of particles detected by Counter Tube - Type B. All measurement data is recorded in the table and based on the data, the graph was plotted to compare the accuracy of the measurement reading between Alpha Thickness Gauging Method and destructive method of Scanning Electron Microscope (SEM). Verification was performed on the graph to determine the accuracy of the measurement readings obtained from the experiment using a sample of unknown coating thickness. Results showed that the use of radioactive material Americium-241 can produce better measurement readings than the use of Radium-238. During the experiment carried out several factors that have affected the accuracy of the measurement readings were detected. In future study, these factors can be improved in order to produce more accurate measurement readings.

ABSTRAK

Ketebalan lapisan mata alat merupakan suatu fungsi yang penting untuk melindungi dan meningkatkan prestasi pemotongan dalam pemesinan. Dengan lebih tepat lagi, pengukuran ketebalan lapisan mata alat ini mampu mengekalkan kualiti produk dan mengawal kos pengeluran. Projek ini adalah untuk mengkaji dan mengukur ketebalan lapisan mata alat dengan menggunakan Kaedah Tolok Ketebalan Alpha. Projek ini mengetengahkan pertimbangan terhadap kesan kepada ketepatan pengukuran apabila menggunakan kaedah ini. Bahan radioaktif yang digunakan sebagai ujikaji dalam projek ini adalah Radium-226 dan Americium-241, sementara bahan lapisan pada mata alat yang di ukur adalah diperbuat daripada Aluminum Titanium Nitride (TiAIN). Terdapat 10 jenis mata alat yang digunakan mempunyai ketebalan yang berbeza untuk di ukur. Bacaan pengukuran tertera pada Kaunter Gieger Muller yang mana berfungsi untuk rekod jumlah zarah yang dikesan oleh Kaunter Tiub – Jenis B. Semua data pengukuran direkodkan di dalam satu jadual dan berdasarkan data tersebut, graf yang telah diplot untuk membandingkan ketepatan bacaan pengukuran antara Kaedah Tolok Ketebalan Alpha dan kaedah pemusnah iaitu Scanning Elektron Microscope (SEM). Pengesahan telah dilakukan ke atas graf tersebut bagi menentukan ketepatan bacaan pengukuran yang diperolehi daripada hasil experimen menggunakan sampel tidak diketahui ketebalan lapisannya. Keputusan menunjukkan bahawa penggunaan bahan radioaktif jenis Americium-241 dapat menghasilkan bacaan pengukuran yang lebih baik berbanding jenis Radium-238. Sepanjang experimen dijalankan terdapat beberapa faktor yang telah mempengaruhi ketepatan bacaan pengukuran telah dikesan. Bagi kajian akan datang, faktor-faktor ini boleh diperbaiki agar dapat menghasilkan bacaan pengukuran yang lebih tepat.

DEDICATION

To my beloved parents, Mr. Ibrahim Bin Mamat and Mrs. Rohanah Binti Zahari, thank you for your support and thanks for everything. My sisters and brothers, thank you for encouraging me to do well in this writing.

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HSS	-	High Speed Steel
CVD	-	Chemical Vapor Deposition
PVD	-	Physical Vapor Deposition
ANSI	-	American National Standard Institute
NDT	-	Non-Destructive Test
Ra-238	-	Radium-238
Am-241	-	Americium-241
Pu-239	-	Plutonium-239
Co-60	-	Cobalt-60
UV	-	Ultra Violet
TiAIN	-	Titanium-Aluminum-Nitride
WC	-	Tungsten Carbide
SEM	-	Scanning Electron Microscope

CHAPTER 1

INTRODUCTION

1.1 Background of the Project

Coating thickness is an important variable that plays a role in product quality, process control and cost control. Measurement the thickness of cutting tool can be done with many different instruments. Commonly used measuring techniques for coating thickness of cutting tool include destructive coating thickness such as micrometer, vernier caliper and microscope. Understanding the equipment that is available for coating thickness measurement and how to use it is useful to every coating of cutting tool.

This project will study and do analysis on measurement the coating thickness of cutting tool by using radioactive alpha source which is alpha thickness gauging method. The alpha thickness gauging method is nondestructive coating thickness which consists of two basic components; a source of radiation, and a radiation detector. The cutting tool to be measured is placed between the source and detector.

The project will broadly involve a few tasks such as developed nondestructive method to measure the coating thickness of cutting tool by using alpha thickness gauging method and compare with destructive method.

1.2 Problem Statement

Measurement the coating thickness of cutting tool commonly used destructive measuring techniques such as height measurement (measuring before and after with a micrometer) and optical cross-sectioning (cutting the coated part/tool and viewing the cut microscopically). These techniques are time-consuming, difficult to perform and are subject to user interpretation and other measurement errors. Although this method's principles are easy to understand, opportunities abound for introducing errors. It takes skill to prepare the sample and interpret the results. Also, adjusting the measurement reticule to a jagged or indistinct interface can generate inaccuracy, particularly between different users. This method is used when inexpensive, nondestructive methods aren't possible, or as a means of confirming nondestructive test results.

1.3 Objectives

i. To develop a method to measurement the cutting tool coating thickness by using alpha thickness gauging method.
ii. To investigate the accuracy of alpha thickness gauging method.
iii. To identify factors which influenced measurement the coating thickness of cutting tools by using alpha thickness gauge.

1.4 Scope

The project will involve the experimentation on the several critical factors should be considered when evaluating instrument in measurement the coating thickness of cutting tool. Some of the consideration need to be evaluated is the variation within the sample being measured, resolution of the readings and the accuracy of the actual measurement.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Literature review or academic study is one earlier research process to help in process introduce new method for measurement the coating thickness of cutting tool. Through this method early retrieval on a project weakness and advantage will be acquired through study method and comparison with present method / equipment. With this literature review also a product produced can fulfill current need without fomenting.

2.2 Coating of Cutting Tool

Coatings have become such an indispensable part of most cutting tool grades that 70 - 75% of all carbide tools are now coated. Coatings improve wear resistance, they increase tool life, and they broaden the application range of a given grade, and enable use at higher speeds. By improving performance, coatings are helping cutting tool manufacturers respond to changing workpiece materials and process requirements. Today's machining operations can involve high-speed machining, dry machining, use of more near-net-shape workpieces, tighter surface finish and dimensional tolerances, and increased use of untended machining, which places a premium on edge security and tool reliability.

Improved wear resistance results from coating materials' high hardness, chemical inertness, and low coefficients of friction. In uncoated tools, increased wear resistance-obtained by increasing the amount of hard carbides in the material, as described in part 1 of this series of articles--is traded off against lower toughness.

The processes used to add coatings to cutting tools-regardless of whether the substrate is High Speed Steel (HSS), cemented carbide, cermets, ceramic, or a super hard material--are chemical vapor deposition (CVD) and physical vapor deposition (PVD). The process selected depends on tool material composition and geometry, and on the intended application of the tool. (Destefani, 2002)

2.3 Cutting Tool Material

As rates of metal removal have increased, so has the need for heat resistant cutting tools. The result has been a progression from high-speed steels to carbide and on to ceramics and other super hard materials.

Developed around 1900, high-speed steels cut four times faster than the carbon steels they replaced. There are over 30 grades of high-speed steel, in three main categories: tungsten, molybdenum, and molybdenum-cobalt based grades. Since the 1960s the development of powdered metal high-speed steel has allowed the production of near-net shaped cutting tools, such as drills, milling cutters and form tools. The use of coatings, particularly titanium nitride, allows high-speed steel tools to cut faster and last longer. Titanium nitride provided a high surface hardness, resist corrosion and it minimizes friction.

In industry today, carbide tools have replaced high-speed steels in most applications. These carbide and coated carbide tools cut about 3 to 5 times faster than high-speed steels. Cemented carbide is a power metal product consisting of fine carbide particles cemented together with a binder of cobalt. The major categories of hard carbide include tungsten carbide, titanium carbide, tantalum carbide and niobium carbide. Each type of carbide affects the cutting tools characteristic differently. For example, a higher tungsten content increase wears resistance, but reduces tool strength. A higher percentage of cobalt binder increase strength, but lowers the wear resistance.

Carbide is used in solid round tools or in the form of replaceable inserts. Every manufacturer of carbide tools offers a variety for specific applications. The proper choice can double tool life or double the cutting speed of the same tool. Shock-resistant types are used for interrupted cutting. Harder, chemically-stable types are required for high speed finishing of steel. More heat-resistant tools are needed for machining the superalloys, like Inconel and Hastelloy.

There are no effective standards for choosing carbide grade specifications so it is necessary to rely on the carbide suppliers to recommend grades for given applications. Manufactures do use an ANSI code to identify their proprietary carbide product line.

Two-thirds of all carbides tools are coated. Coated tools should be considered for most applications because of their longer life and faster machining. Coating broadens the applications of a specific carbide tool. These coatings are applied in multiple layers of under 0.001 of an inch thickness. The main carbide insert and cutting tool coating materials are titanium carbide, titanium nitride, aluminum oxide and titanium carbon nitride. (Society of Manufacturing Engineers, 2002)

2.4 Coating Thickness Measurement

Coatings perform a variety of important functions including protecting and beautifying outdoor structures and manufactured 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 dependant 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 technologies available for coating thickness measurement.

Measuring techniques are either destructive or non-destructive. Non-destructive methods include magnetic, eddy current, ultrasonic, and micrometer measurement. Destructive methods include cross sectioning and gravimetric (mass) measurement. Methods are also available for pre-cured liquid and coating powder measurement. (Beamish, 2008)

2.4.1 Destructive Tests

Destructive technique is to cut the coated part in a cross section and measure the film thickness by viewing the cut microscopically. Another cross sectioning technique uses a scaled microscope to view a geometric incision through the dry-film coating. A special cutting tool is used to make a small, precise V-groove through the coating and into the substrate. Gages are available that come complete with cutting tips and illuminated scaled magnifier.

While the principles of this destructive method are easy to understand, there are opportunities for measuring error. It takes skill to prepare the sample and interpret the results. Adjusting the measurement reticule to a jagged or indistinct interface may create inaccuracy, particularly between different operators. This method is used when inexpensive, nondestructive methods are not possible, or as a way of confirming nondestructive results. ASTM D 4138 outlines a standard method for this measurement system. (Beamish, 2008)

2.4.2 Non-destructive Test (NDT)

Non-destructive testing (NDT) used to detect, inspect, and measure flaws, bond integrity, and other material conditions without permanently altering or destroying the examined part or product. (Lomax, 2009)

2.4.2.1 A Method to Measure the Mean Thickness and Non-uniformity of Non-uniform Thin Film by Alpha-Ray Thickness Gauge

The alpha-ray thickness gauge is used to measure non-destructively the thicknesses of thin films, and up to the present day, a thin film with uniform thickness is only taken up as the object of alpha-ray thickness gauge. When the thickness is determined from the displacement between the absorption curves in the presence and absence of thin film, the absorption curve must be displaced in parallel. When many uniform particles were dispersed as sample, the shape of the absorption curve was calculated as the sum of many absorption curves corresponding to the thin films with different thicknesses.

By the comparison of the calculated and measured absorption curves, the number of particles, or the mean superficial density can be determined. This means the extension of thickness measurement from uniform to non-uniform films. Furthermore, these particle models being applied to non-uniform thin film, the possibility of measuring the mean thickness and non-uniformity was discussed. As the result, if the maximum difference of the thickness was more than $0.2 mg/cm^2$, the non-uniformity was considered to distinguish by the usual equipment. In this paper, an alpha-ray thickness gauge using the absorption curve method was treated, but one can apply this easily to an alpha-ray thickness gauge using alpha-ray energy spectra before and after the penetration of thin film. (Miyahara, Yoshida and Watanabe, 1977)

2.5 Radioactive Source

Radiation sources, utilizing either radioactive materials or radiation generators, are used throughout the world for a wide variety of peaceful purposes, in industry, medicine, research and education. They are also used for various military purposes. Many are in the form of sealed sources with the radioactive materials firmly contained or bound within a suitable capsule or housing. The risks posed by these sources and materials vary widely, depending on such factors as the radionuclide, the physical and chemical form, and the activity. Unless breached or leaking, sealed sources present a risk from external radiation exposure only. However, breached or leaking sealed sources, as well as unsealed radioactive materials, may lead to contamination of the environment and the intake of radioactive materials into the Human body.

The International Basic Safety Standards provide an internationally harmonized basis for ensuring the safe and secure use of sources of ionizing radiation. Because of the wide variety of uses and activities of radiation sources, a categorization system is necessary so that the controls that are applied to the sources are commensurate with the radiological risks. (Vienna, 1996)

2.5.1 Concept of Ionizing Radiation

The energy emitted by non-ionizing radiation is less than $30 - 34eV$. Radiations that have the energy above the aforementioned value are categorized as ionizing radiation. Since they cannot be detected by our senses, special devices must be used. (MINT, 2005)