DECLARATION

I hereby, declare this thesis entitled "Machining Performance of Titanium Carbide (TiC) as Tool Coating" is the results of my own research except as cited in the reference.

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KOLEJ UNIVERSITI TEKNIKAL KEBANGSAAN MALAYSIA

BORANG PENGESAHAN STATUS TESIS*

JUDUL: MACHINING PERFORMANCE OF TITANIUM CARBIDE (TiC) AS TOOL COATING.

SESI PENGAJIAN : 2005 / 2006

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NATIONAL TECHNICAL UNIVERSITY COLLEGE OF MALAYSIA

Machining Performance of Titanium Carbide (TiC) as Tool Coating

Thesis submitted in accordance with the requirements of the National Technical University College of Malaysia for the Degree of Bachelor of Engineering (Honours) Manufacturing (Process)

By

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ABSTRACT

This paperwork contain the report of machining performance of tool coating when apply in machining process. The aim of this paperwork is to present flank wear characteristics of titanium carbide (TiC) as coated material on cemented carbide tool during machining a medium carbon steel (AISI 1045) material in dry turning. Machining performance is determined according to tool wear, tool life and surface finish that obtained. The nominal (starting) workpiece diameter is 50mm and the cutting speeds used are 300, 400, 500, and 600 m/min with feed rate and depth of cut is 0.2mm/rev and 0.5mm, respectively. The cutting time is considered in this machining test to identify the tool life. Four interval of cutting time has been setup for each cutting speeds which is 5, 7.5, 10 and 12.5 min. From that, the appropriate cutting parameters for each cutting tool will be identify depending on tool wear and tool life. Tool wear that appeared is analyzed by flank wear as recommended in ISO 3685 (1993): Tool life testing with single point turning tools. From study, the rate of wear growth and wear mechanism at the end of tool life was investigated in detail using scanning electron microscope (SEM). From the photographs of progressive wear, it has been observed that the time taken for the cutting edge of TiC coated carbide tools to initiate cracking and fracturing is longer when cutting at low speed than at high speed such as 600m/min. The critical cutting speed influence the surface finish of work material. Tool variables, workpiece variables and setup variables are factor that affect surface roughness in rough turning.

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LIST OF ABBREVIATIONS, SYMBOLS, SPECIALIZED NOMENCLATURE

AISI	-	American National Standard Institute
Al_2O_3	-	Aluminum Oxide
CBN	-	Cubic Boron Nitride
CrC	-	Cromium Nitride
CNC	-	Computer Numerical Control
CVD	-	Chemical Vapor Deposition
d.o.c	-	Depth of cut
Da	-	Initial diameter
Db	-	Final diameter
H.S.S	-	High Speed Steel
ISO	-	International organization of Standardization
MRR	-	Metal Removal Rate
MTCVD	-	Medium Temperature Chemical Vapor Deposition
M-series	-	Molybdenum series
PVD	-	Physical Vapor Deposition
Ra	-	Arithmetic average
Rq	-	Root mean square value
Rpm	-	revolution per minute
Sfpm	-	Surface feet per minute
TiAlN	-	Titanium Aluminum Nitride
TiCN	-	Titanium Carbonitride
TiN	-	Titanium Nitride
TiC	-	Titanium Carbide
T-series	-	Tungsten series
WC	-	Tungsten Carbide

CHAPTER 1
INTRODUCTION

1.1) INTRODUCTION

Machining performance of tool coating is subjected to investigate the capabilities and limitations of coating material to different substrate (base material of cutting tool) in machining. To achieve the machining performance of tool coating, the tool's material must possess high strength at elevated temperature, good oxidation resistant, low coefficient of thermal, resistant to wear, chemical reactance resistance and high conductivity and can withstand for a long time for machining (Kalpakjian and Schmid S.R, 2001). In addition to increasing the tool life, hard coating deposited on cutting tools allows for improved and more consistent surface roughness of the machined workpiece. The surface roughness of the machined workpiece changes as the geometry of the cutting tool changes due to wear, and slowing down the wear process means more consistency and better surface finish.

In this project, TiC (Titanium Carbide) as coating material is used to measure it performance during dry turning of Medium Carbon AISI 1045. The substrate used is Tungsten Carbide (WC). In this project, the work will involve the setting-up and operating the machining trial using TiC coatings tool followed by detailed examination of the tools that used and the workpiece material characteristic using scanning electron microscopy, and Portable Surface Roughness Tester. The important process variables in machining are tool's shape and material, cutting conditions such as speed, feed and depth of cut, the material characteristics of the workpiece and the machine tool are considered in analyzing the performance of a machine.

ISO 3685 (1993): Tool life testing with single point turning tools is refer as guide for this project in measuring tool wear and tool life. The results will be obtained importantly in the development of the next generation of cutting tool coatings by quantifying their performance and capability using the specific controlled and scientific test.

1.2) GOAL

The goal of this study was to improve the understanding of the effect of coating materials (Tic coatings) on the performance of tungsten carbide cutting tools. To achieve this goal, the machining test was conducted with CNC lathe machine by using commercial coating (TiC) inserts. In this study, the performance of the cutting tool is evaluated by considering the progression tool wear, toll life and surface finish of the work material.

1.3) OBJECTIVE OF PROJECT

The specific objectives for Machining Performance of Titanium Carbide as Tool Coating for this project are:

i.) To investigate the capabilities and limitations of TiC (Titanium carbide) as coating on cemented carbide.

ii.) To study the tool life and tool wear progression on TiC tool used as the coating element.

iii.) To study the surface finish throughout the machining.

iv.) To access and analyze the results obtained for tool and evaluated their performance based on the effects of the coating material used.

1.4) SCOPE OF PROJECT

Coated carbide tools have found widespread use in today's metal cutting industry, bringing about significant improvements in tool performance and cutting economy through lower tool wear, reduced cutting forces, and better surface finish of the workpiece. For this project, the work will involve the setting-up and running of machining trial using tool coating followed by detailed examination of the used tools and work material using scanning electron microscopy, profile projector (vertical optical comparator), and portable surface roughness. The tool wear, tool life, and surface finish that will be obtain during machining trial is examine and analyze their result to relate with capabilities and limitations of tool coating (TiC) when applied to cutting tools. From that, the machining performance of the machining process that related with tool coating (cutting tool) will be find out. The results obtained will be extremely important in helping to develop the next generation of cutting tool coatings by quantifying their performance using series of controlled and scientific tests. There is also the intention to publish the results of this work.

1.5) PROBLEM STATEMENT

The coating of carbide cutting tools with thin surfaces layers of materials such as titanium carbide (TiC) has now been carried out for many years in order to improve their machining performance. The use of coating materials to enhance the performance of cutting tool is not a new concept. The first coated cemented carbide indexable inserts for turning were introduced in a969 and had an immediate impact on metal cutting industry. These first generation TiC coated carbide tools were initially used in interrupted cutting applications such as the milling of steels. However, over the last few years there has been a considerable amount of interest in a new generation of coatings with significantly improved performance compared to conventional coatings. Today, 70% of cemented carbide tools used in the industry is coated. There are now efforts to produce the cutting tool locally thorough knowledge of the cutting process so that requirements of the tools are correctly identified.

CHAPTER 2
LITERATURE REVIEW

The literature review is conducted to achieve the objectives for this research. The literature is included information on carbide tools used in turning, coating materials for cutting tools, wear observation during turning operations and surface finish of the machined work material. All of this information is served as guideline in the course of the study.

Cutting tools are very important class of advanced engineering materials for the manufacturing technologies. A variety of cutting tool materials is used to machine various materials in the manufacture of useful components. On these, nearly 40-45% of tools are cemented carbides and an equal amount of high speed steel tools. The application of hard, wear resistance coating on cutting tools began in mid-1969s, and today nearly 70% of cutting tools are coated (Dr. Deepak, 1998).

The cutting tool is the component most stressed, and therefore limits the performance in machining operations. Among manifold tribological stresses, thermal and mechanical loads affect the cutting tool edges in a continuous or intermitting way. As a result, in addition to good wear resistance, high thermal stability and high mechanical strength are properties required for cutting materials (Otto Knotek, 2001).

The cutting tool material must possess a greater hardness than the workpiece material. The cutting tools are made of very hard materials and tend to fracture when they fail. Typically, cutting tool only cut in one direction. If the cutting is used in the opposite direction, the cutting tool, machine tool and workpiece may be damaged (George Schneider, 1999).

Cemented carbide is usually made by mixing tungsten powder and carbon at high temperature in the ratio of 94 and 6 percent respectively by weight. The cemented carbide has high hardness over a wide a range of temperatures, high elastic modulus, thermal conductivity, and low thermal expansion, versatile and cost effective tool thereby suitable for a wide range of application. Cemented Carbides can be used at much higher cutting speeds than HSS (High Speed Steel) or cast alloy material. However, Cemented Carbides are not tough and cannot be shaped after sintering. The two basic groups of carbides used for machining operation are tungsten carbide and titanium carbide (Steve and Albert, 1997).

Cutting materials for extreme requirements (for example, interrupted cuts or machining of high strength materials) can consequently not be made from one single material, but may be realized by composite material. Surface coating may improve the tribological properties of cutting tools in an ideal way and therefore allow application of tough or ductile substrate material, respectively (Otto Knotek, 2001). Due to their significantly higher hardness, carbide cutting tools are more widely used in the metal working industry and provide the best alternative for most turning operations (Che Haron, Ginting and Goh, 2001).

2.1) COATING

Before tool coated is used in industrial, cemented carbide is preferred as cutting tool because its microstructure shows that it is bulk hardness and toughness. However, it suffers from severe crater wear when cutting steels at high speed. Nowadays, the solution is use coated tools as cutting tool because of their bulk optimized to resists failure and their surfaces coated to resist wear (John D. Christopher, 1998).

The use of coated cutting tools to machine various materials represents state of the art machining technology, and today's machining processes are becoming increasingly demanding on cutting tool materials (Grzesik and Nieslony, 2000). The main purpose of tool coating is to improve productivity by allowing higher cutting speeds or feed rates.

There are two factors to be considered in evaluating inserts coatings which is the materials or the materials used, and the process by which they are applied. Both impact insert system performance. The coating itself acts the interface between the workpiece and the cutting tool. Depending on the application, coating can provide wear resistance, abrasion and crater resistance, built up edge resistance, chemical resistance or a simple reduction in friction which lowers cutting temperatures (Karl Katt, 1997).

Schintmeister et al (1989) had summarized the effect of coatings in the following statement:

1. Reduction in friction, in generation heat, and in cutting forces
2. Reduction in the diffusion between the chip and the surface of the tool, especially at higher speeds (the coating acts as a diffusion barrier)
3. Prevention of galling, especially at lower cutting speeds.

2.1.1) TYPES OF COATING TECHNIQUES

There are four major coating technologies used in the cutting tool industry today. These are differentiated primarily by the temperature at which they operate. This is important, because the temperature at which the coating is applied direct impacts the performance of substrate properties. The most common coating technology is chemical vapor deposition (CVD) which operates at temperature of roughly 1,000°C. Nearly as common is physical vapor deposition (PVD), which operates at the other end of the temperature spectrum in the 400°C range (Karl Katt, 1997).

2.1.1.1) Chemical Vapor Deposition (CVD)

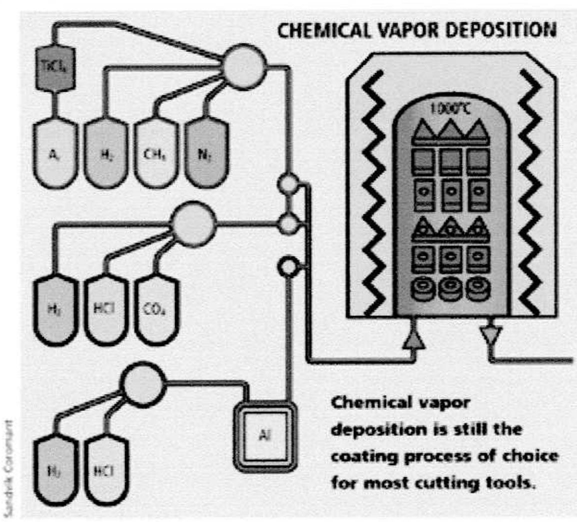

Figure 2.1: Chemical Vapor Deposition process (Jim Destefani ,2000)

Chemical Vapor Deposition (CVP) was used to produce the first cutting tool coatings in the late 1960s and early 1970s (Venkatesh, 1991). In the CVD process, the tools are heated in a sealed reactor to about 1000°C (1830°F). Gaseous hydrogen and volatile compounds supply the metallic and nonmetallic constituents of the coating materials, which include Titanium Carbide (TiC), Titanium Nitride (TiN), Titanium Carbonitride (TiCN) and Aluminum Oxide (Al_2O_3). CVD is also used to produce diamond thin films for graphite and nonferrous cutting applications. The thickness of CVD coatings can range from 5~20μm (Jim Destefani ,2000).

However, the high deposition temperature (950-1059°C) during CVD results in diffusion of chemical elements from the carbide substrate to the coating during growth. The main effect is an embrittlement of the coating edge (Soderberg, Sjostrand et al. 2001). To improve the CVD process, the medium temperature CVD (MTCVD) process was developed in the 1980s to allow coating deposition at temperature from 700 to 900°C (1300~1650°F). The temperature in this MTCVD is reducing and works in faster deposition to maintain toughness of the substrate material, and reduce thermally induced cracking in the coating. Coating that produce by MTCVD processes are tougher than traditional CVD coatings.