UNIVERSITI TEKNIKAL MALAYSIA MELAKA

THE PERFORMANCE OF CARBIDE TOOLS WHEN HARD TURNING AISI D2 TOOL STEEL

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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DECLARATION

I hereby, declared this report entitled “The Performance of Carbide Tools When Hard Turning AISI D2 Tool Steel” is the results of my own research except as cited in references.

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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) with Honours. The member of the supervisory committee is as follow:

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(Dr. Ahmad Kamely Bin Mohamad)

APPROVAL

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ABSTRACT

The machining of hardened steels has been widely investigated by researchers today. CBN is widely used as a cutting tool to machine hardened steel, but the cost of CBN is high. Carbides have high hardness over a wide range of temperatures, high elastic modulus, high thermal conductivity, and low thermal expansion and more important it is cost-effective cutting tool for a wide range of applications. In this study the performance of carbide tools when hard turning AISI D2 tool steel of 55 HRC has been investigated. Tool wear and wear mechanisms are analyze by using image analyzer and Scanning Electron Microscope. Surface roughness is measured by using portable surface roughness tester, SJ-301. From the results it has been observed that time taken for carbide cutting edge to start cracking and fracturing is longer when cutting at low speed than a high speed. Surface finish in the range of 1.05 μm to 2.25 μm was obtained in this study. Coated carbide cutting tools shows better performance compared to uncoated carbide cutting tools. It is found that cutting speed play a major role in determining the tool life and roughness of the surface.

ABSTRAK

Pada masa kini, kebanyakan penyelidik telah mengkaji pemesinan besi-besi keras. CBN biasanya di gunakan sebagai mata alat untuk pemesinan besi-besi keras, tetapi harga mata alat CBN adalah tinggi. Karbida digunakan sebagai mata alat menggantikan CBN kerana ia mempunyai kekerasan yang dapat menahan suhu yang tinggi, ia juga merupakan konduktor tenaga yang baik, dan yang paling penting harganya lebih ekonomik. Dalam kajian ini, pelaksanaan mata alat karbida semasa pemotongan AISI D2 tool steel, 55 HRC telah dikaji. Kehausan dan mekanisme kehausan mata alat telah di analisis menggunakan stereo zoom microscope dan scanning electron microscope. Kekasaran permukaaan telah di kaji menggunakan portable surface roughness tester, SJ-301. Hasil kajian yang telah dikaji menunjukkan masa yang di ambil untuk mata alat karbida mula merekah dan rosak adalah lebih lebih lama apabila pemesinan pada halaju yang rendah berbanding halaju yang tinggi. Permukaan terbaik dalam lingkungan 1.05 μm hingga 2.25 μm telah didapati dalam kajian ini. Mata alat karbida yang di sadur menunjukkan pelaksanaan yang lebih baik berbanding dengan mata alat karbida yang tidak di sadur. Kajian ini juga membuktikan halaju pemesinan memainkan peranan penting untuk menentukan jangka hayat mata alat dan kekasaran permukaan.

DEDICATION

For My beloved family and friends

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First of all, lot of thanks to Allah to give me the chance and strength to complete my project “The Performance of Carbide Tools when Hard Turning AISI D2 Tool Steel”. Hereby, I would like to thank my supervisor, Dr. Ahmad Kamely Bin Mohamad, who supervised and helped me during this project until I achieve the objectives of this project. He also always gives me advice, supports, and motivation during studying and finishing this task. Then, I would like to thank for the technician of FKP, because always help me in complete this task especially during using conventional lathe machine.

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LIST OF ABBREVIATIONS

AISI	-	American Iron and Steel Institute
Al_2O_3	-	Aluminum Oxide
BUE	-	Built-up edge
C	-	Carbon
CBN	-	Cubic Boron Nitride
CNC	-	Computer Numerical Control
CVD	-	Chemical Vapor Deposition
d.o.c	-	Depth of cut
HRB	-	Hardness Rockwell B
HRC	-	Hardness Rockwell C
ISO	-	International Standardization Organization
kW	-	Kilowatt
MQL	-	Minimum Quantity Lubrication
PVD	-	Physical Vapor Deposition
Ra	-	Arithmetic average
Rpm	-	revolution per minute
SEM	-	Scanning Electron Microscopy
TiAIN	-	Titanium Aluminium Nitride
TiC	-	Titanium Carbide
TiCN	-	Titanium Carbon Nitride
TiN	-	Titanium Nitride
TiO	-	Titanium Oxide
WC	-	Tungsten Carbide

CHAPTER 1

INTRODUCTION

1.1 Overview

In this study will be discuss and discover about the performances of carbide tools when finish hard turning AISI D2 tool steel. The equipment that suitable for this project is lathe machine to measure the flank wear and surface roughness tester to measure the surface roughness. This project will be specific on to identify the types of the wear and surface roughness that will occur when hard turning AISI D2 tool steel.

1.2 Background of The Problem

The machining of hardened steels using CBN and carbide cutting tools has been widely investigated by researchers today. CBN is a widely use as a cutting tool to machining hardened steel, but because of the high cost of the CBN, many of the researchers today change the CBN cutting tool and use carbide tools to machining the steel (Marques, 2008). Carbides (also known as cemented and sintered carbides) were introduced in the 1930s. Because of their high hardness over a wide range of temperatures, high elastic modulus, high thermal conductivity, and low thermal expansion, carbides are among the most important, versatile, and cost-effective tool and die materials for a wide range of applications (Kalpakjian and Schmid, 2001).

The various forms of damage of the cutting tool develop during cutting are tool wear, cracks, and tool breakage. The basic feature wear that always occur when do machining operation are flank wear, crater wear, and notching (Tlusty, 2000). These forms of wear grow rather uniformly with cutting time. The conditions that induce tool wear are high localized stresses at the tip of the tool, the temperatures, especially along the rake face, sliding of the chip along the rake face, and sliding of the tool along the newly cut workpiece surface (Kalpakjian and Schmid, 2001). Tool wear is a major consideration in all machining operations, as a mold and die wear in casting and metalworking. The wear of carbides tool adversely affect tool life of carbides, the quality of the machined surface and its dimensional accuracy, and consequently, the economics of cutting operations. The wear is a gradual process, much like the wear of the tip of an ordinary pencil. The rate of tool wear depends on tool and workpiece materials, tool geometry, process parameters, cutting fluids, and the characteristics of the machine tool (Kalpakjian and Schmid, 2001).

There are a large number of steel parts which are hardened that usually need a finishing operation after the heat treatment process. Hard machining is a cost-effective, high productivity and flexible machining process for ferrous metal workpieces that are often hardened above 40 HRC and up to 62 HRC. This process has become a popular technique in manufacturing of gears, shafts, bearings, cams, forgings, dies, and molds. Hard machining is performed dry using carbide cutting tools due to the required tool material hardness. The process stability and the reliability are dependent upon wear characteristics of the tool material (Karpat et al. 2007).

AISI D2 tool steel is a one of the most widely used hardened steels used for many types of tools and dies, and other applications where high wear resistance and low cost are required (Davim and Figueira, 2007).

1.3 Problem Statement

Before carbide was found to cut the machining, many factories used CBN as a cutting tool. The problem that usually occurred when used the hard turning process are the high cost of the CBN. After carbide was found, it's used to replace CBN tool as a cutting tool to machining steel because it's more economics. The investigation of the carbide performance will be discussed in this study.

The wear represents a major index of the performance criteria for cutting tool. The wear mechanisms, which usually cause cutting tools to fail, are abrasive wear, diffusion wear, attrition wear, plastic deformation and fracture. In this study, the mechanism of the wear that will occur on carbide tools when hard turning AISI D2 tool steel will be identified.

Nowadays, there are many developing of cutting tool new combinations of coatings and substrates to precisely match different work piece and materials and operations. This study used coated carbide (TiC) and uncoated carbide as a cutting tool. Nevertheless, the suitability of coated carbide and uncoated carbide cutting tool when turning AISI D2 cold work tool steel (55 HRC) is yet to be investigated. Additionally, the better carbide cutting tool that will be used can be defined after the investigation is done.

1.4 Objectives of The Study

The objectives of this research are:

a) To investigate the effect of cutting parameters on the tool wear and surface roughness.
b) To describe the wear mechanism that occurred when hard turning AISI D2 tool steel.
c) To study the performance of coated carbide and uncoated carbide.

1.5 Scope of The Project

The scopes for this project are:

a) This experiment will analyze flank wear because it is predominant wear in all machining operations. Its effects tool life, the quality of the machined surface and its dimensional accuracy, and consequently, the economics of cutting operations. Wear is a gradual process, much like the wear of the tip of an ordinary pencil. The rate of flank wear depends on tool and work piece.

b) Surface roughness is measured to study about performance of carbides as a cutting tool to turning AISI D2 tool steel. The surface roughness value is highly dependent on the cutting conditions (cutting speed, feed rate, and depth of cut).

c) To study about the wear mechanism that will occur in this experiment.

1.6 The Significance of The Study

The significance of this study is about carbides tool wear performances when hard turning AISI D2 tool steel. This investigation is focus at flank wear and surface roughness. Low value of flank wear and surface roughness can reduce the wear and give a long life tool, improve fatigue life, reduce the coefficient of friction, and improve corrosion resistance. An understanding of the carbides performances will give alternative to the manufacturing industries to exploit low costs cutting tools in hard turning of AISI D2 tool steel (55 HRC).

CHAPTER 2

LITERATURE REVIEW

2.1 Machining Overview

Hard turning is a machining operation that is complex nonlinear and coupled thermo mechanical process. The complexities are due to large strain and high strain-rate in the primary shear zone and due to the contact and friction between the chip and cutting tool along the secondary shear zone. In addition, complexities are also caused by local heat generation through the conversion of plastic work in the chip during chip formation and the frictional work between the tool and chip (M.W. Knufermann, 2003). Hard turning is a single-point machining process (i.e., one carried out on a lathe) carried out on "hard" materials (where "hard" is defined as having a Rockwell C hardness greater than 45). The process is intended to replace or limit traditional grinding operations that are expensive, environmentally unfriendly, and inflexible (http://en.wikipedia.org/wiki/Hard_turning).

The conventional lathe machine is use in this project. This project will be specific on the flank wear that will occur when finish hard turning AISI D2 tool steel. The conventional lathe basic principle is the work piece is held and rotated on its axis while the cutting tool is advanced along the lines of a desired cut. The lathe machine is one of the most versatile machine tools used in industry. It is useful for fabricating parts and/or features that have a circular cross section. There are so many operations which the lathe machine can perform, but the most common are boring, drilling, facing, knurling, threading, and turning. In this experiment, turning will be done using conventional lathe machine (Kalpakjian and Schmid, 2001).

2.2 Hard Turning

2.2.1 The Important Of Hard Turning

Hard turning is a cost- effective, high productivity and flexible machining process for ferrous metal work pieces that are often hardened above 40 HRC and up to 62 HRC (Bourithis et al. 2006). Hard machining is performed dry using carbide cutting tools due to the required tool material hardness (M.W. Knufermann, 2003). Hard turning is a lathe machining process where most of the cutting is done with the nose of the inserts. The process stability and the reliability are dependent upon wear characteristics of tool material. Flank and crater wear governs the end of tool life. While flank wear progress is steadier, crater formation on the rake face is highly influenced by thermal conditions and associated chemical wear (C.H. Haron et.al, 2001). Therefore, majority of earlier of hard turning research concerned with composition, thermal and wear characteristic of cutting tools, in addition to the effects of work material hardness, tool geometry and cutting conditions on the surface integrity of the finish machined parts (T. Ozel et al, 2007).

Recent advances in tool radius geometry have been achieved to improve the surface roughness and tool life when used in turning cold work tool steels such as AISI D2 (Davim and Figueira, 2007). AISI D2 is the one of the most important hardened steels used for many types of tools and dies, and other applications where high wear resistance and low cost are required. Lima et al. (2005) investigated the machinability of hardened steels AISI 4340 and AISI D2 at different levels of hardness and using a range of cutting tool materials. The results indicated that when turning AISI 4340 steel the surface roughness improved with cutting velocity and deteriorated with improved feed rate, while depth of cut (DoC) presented little effect on the surface roughness values. Turning AISI D2 steel with carbide insert resulted in a surface finish as good as that produced by cylindrical grinding.

Bourithis et al. (2006) compared AISI D2 and O1 hardened to 60 HRC in three different modes of wear, namely adhesion, three-body, and two-body abrasion. The results show that the steel microstructures play the most important role in determining the wear properties. El-Wardany et al. (2000) studied the quality and integrity of the surface produced and the effects of cutting parameters and tool wear on chip morphology during high-speed turning of AISI D2 cold work tool steel in its hardened state (60–62 HRC). The metallographic analysis of the surface produced illustrates the damage surface region that contains geometrical defects and changes in the sub surface metallurgical structure. The types of surface damage are dependent on the cutting parameters, tool geometry and the magnitude of the wear lands.

Hard turning refers to the turning of hardened steels with a hardness of beyond 45 HRC. The hardness can even reach 68 HRC. This technique became a profitable alternative for finish machining due to advantages in economical and ecological aspects. High material removal rate and relatively low tool cost compared to the incumbent grinding as the finishing operation are some of the economical benefits. Additionally, stricter health and environment regulations and also post-production cost consideration led to the minimized use of coolant whenever feasible and hard turning has been successfully performed in dry condition (Mamalis et al. 2002). Despite its significant advantages, the lack of data concerning surface quality and tool wear for the many combinations of workpiece and cutting tool impedes the acceptance of hard turning by the manufacturing industry (Pavel et al. 2005). Moreover, the command tools used in hard turning, PCBN and ceramic, are relatively high in price. Some applications in the mould and die industry have been identified to require parts made of hardened steels within the moderate range of hard turning (45-48 HRC). Using advanced and consequently expensive cutting tools for these moderate hardness ranges may hinder the economical benefit of hard turning (Noordin et al. 2007).

Hard turning is defined as the process of single point cutting of part pieces that have hardness values over 45 RC but more typically are in the 58-68 RC range. The range of hard turned applications will vary based upon the part requirements, tolerance levels, surface finish and very importantly the machine tool. The advantages of the hard turning technology are:

a) The lathe offers the versatility to "Soft Turn" and Hard Turn on the same machine tool. A single machine performing the work of two has the added benefits of freeing up vital floor space and being a much lower capital investment.
b) Metal removal rates with hard turning are 4 to 6 times' greater than equivalent grinding operations.
c) Single-point turning of complex contours is routine on a lathe, without the need for costly form wheels.
d) Multiple operations can be turned with a single set-up, resulting in less part handling and a reduced opportunity for part damage.
e) Hard turning can achieve low micro-inch finishes. Surface finishes ranging from .0001 mm to .0004 mm are very common.
f) The hard turn lathe is generally more adaptable as configuration changes are introduced. Lathes are also able to process small batch sizes and complex shapes.

Hard turning is a viable process that has real and measurable economic and quality benefits. This is particularly true with a machine tool that has a high level of dynamic stiffness and the necessary accuracy performance. The more demanding the application in terms of finish, roundness and size control, the more emphasis must be placed upon the characteristics of the machine tool. The hard turning process is similar enough to conventional "soft" turning that the introduction of this process into the normal factory environment can happen with relatively small operational changes. Even though many users choose to maintain the confidentially of their hard turning operations, the general knowledge of the implementation strategies is becoming more widespread and readily available. Extensive, ongoing research has been targeted in the hard turning area, with the likely expectation that additional benefits are soon to come in both the process and machine tool areas. Successful research programs will further enhance the desirability of this already effective process (http://hardingeus.com/usr/pdf/hardturn/ASME.pdf).

2.2.2 Cutting Tool

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 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 (Schneider, G. 1999). Figure 2.1 show the typical carbide inserts with various shapes and chip breaker features.

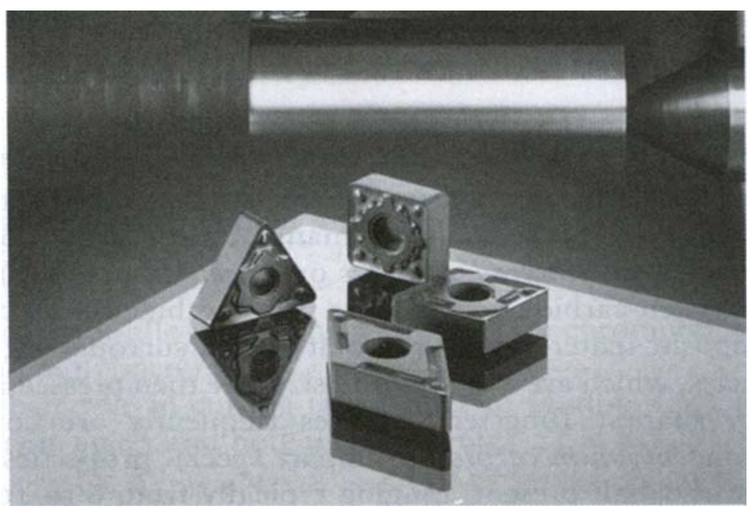

Figure 2.1: Typical carbide inserts with various shapes and chip-breaker features (Kalpakjian and Schmid, 2001).

This project is using carbide as a cutting tool. Carbide tool cutting tools are dividing in two groups:

a) Sintered carbide/cemented carbide

b) Coated carbide