WEAR OF COATED CARBIDE INSERT IN MACHINING OF MILD STEEL

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Manufacturing Engineering.

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I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

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ABSTRACT

This thesis deals with the wear of coated carbide insert in machining of mild steel. Machineability of mild steel is considered good although the cutting temperature is high. The characteristic of mild steel like high strength, high resistance to breakage and high modulus of elasticity has increased the tool wear of the coated carbide when it is used to machining the mild steel for long period. As a result, tool wear of the coated carbide inserts in machining of mild steel still need to be improved. The main objective of this project is to examine the progress of tool wear and determine the crater wear and flank wear of the tool in machining the mild steel in turning process. In this project, 3^3 full factorial design of experiments (DOE) was employed in STATISTICA software to plan and perform the experiment systematically so that any possible experimental error would be minimized. Machining variables considered are cutting length, cutting speed and feed rate. The variables for three levels were 90,120 and 150 m/min for cutting speed, 0.05, 0.1 and 0.15 mm/rev for feed rate and 60, 120 and 180 mm for cutting length respectively. Machining of mild steel was carried out by using the conventional lathe machine. After each experiment, flank and crater wear of the coated carbide inserts was investigated and measured by using optical microscope integrated with Image Analyzer. Experimental data was analyzed in STATISTICA. Flank and crater wear curves were then plotted using Minitab software. The result indicates that feed rate is the most significant parameter that influencing both the flank and crater wear compared to cutting speed and cutting length. Optical micrograph of tool wear shows the crater wear progressed faster than flank wear. Tool wear curves shows that when the number of experiments increases, the flank and crater wear increase monotonically.

ABSTRAK

Tesis ini membentangkan kehausan mata alat pemotong diselaputi karbide dalam memesinkan besi rendah karbon. Kebolehmesinan besi rendah karbon dimesinkan adalah baik walaupun suhu memotong yang sangat tinggi. Ciri-ciri besi rendah karbon seperti kekuatan yang tinggi, keupayaan menahan dari patah, dan nilai modulus kekenyalan yang tinggi ini menyebabkan mata alat pemotong diselaputi karbide akan cepat haus. Ini menunjukkan tahap kehausan mata alat pemotong diselaputi karbide masih perlu dibaikpulih. Objektif utama projek ini ialah untuk memeriksa tahap kehausan mata alat pemotong dan menentukan kehausan atas dan sisi mata alat semasa ianya digunakan untuk memesinkan besi rendah karbon dengan proses larikan. Dalam projek ini, rekaan eksperimen pemfaktoran penuh 3^3 dijanakan dalam perisian STATISTICA untuk mengatur dan menjalankan eksperimen ini secara sistematik untuk mengurangkan apa-apa ralat eksperimen yang mungkin berlaku. Parameter yang dipertimbangkan ialah panjang pemotongan, kelajuan pemotongan dan kadar kelajuan bahan dipotong. Tiga tahap parameter yang digunakan ialah 90, 120 dan 150 m/min untuk kelajuan pemotongan, 0.05, 0.1 dan 0.15 mm/rev untuk kadar kelajuan bahan dipotong serta 60, 120 dan 180mm untuk panjang pemotongan. Proses memesinkan besi rendah karbon dijalankan dengan menggunakan mesin larikan konvensional. Selepas setiap eksperimen, kehausan atas dan sisi mata alat pemotong diselaputi karbide dikaji dan diukur dengan menggunakan mikroskop optikal yang dilengkapi dengan penganalisis imej. Data eksperimen dianalisis menggunakan perisisan STATISTICA. Graf kehausan atas dan sisi mata alat dilukis dengan menggunakan perisian Minitab. Hasil daripada eksperimen ini menunjukkan kadar kelajuan bahan dipotong memberi kesan yang paling utama terhadap kehausan atas dan sisi mata alat dibandingkan dengan kelajuan pemotongan dan panjang pemotongan. Mikrograf optikal untuk kehausan mata alat menunjukkan kadar kehausan atas mata alat adalah lebih cepat daripada sisi mata alat. Graf untuk kehausan mata alat menunjukkan apabila nombor eksperimen meningkat, kehausan sisi dan atas mata alat juga meningkat secara serentak.

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f	Feed Rate, mm/rev
d	Depth of Cut, mm
V_C	Cutting Speed, m/min
L	Cutting Length, mm
D	Workpiece Diameter, mm
N	Spindle Speed, rpm
Kc	Crater Wear, mm
Kb	Flank wear, mm
m	Mean
s	Standard deviation
e	Base of the natural logarithm (2.718)
p	Constant *Pi* (3.142)

LIST OF ABBREVIATIONS

DOE	Design of Experiment
CNC	Computer Numerical Control
TiAlN	Titanium Aluminum Nitride
ANOVA	Analysis of Variance
F	F-test ANOVA
p	Probability value
SS	Sum of Square
MS	Mean of Square
df	Degree of Freedom
L	Linear
Q	Quadratic

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

This chapter provides a short introduction of the project background including several approaches on machining of mild steel. Then the problem statement, objectives, and the scopes of this project on wear of coated carbide insert in machining of mild steel will be introduced.

1.2 PROJECT BACKGROUND

Mild steel have played an important role in bullets, automotive industries, nuts and bolts, chain, hingers, knives, armours, pipes, magnets and many other applications. These materials are used extensively because they possess several excellent properties including extremely brittle and ductile, can be forged when heated, and the price are very low relative to other common material. However, tool wear imposes a major problem in machining mild steel, because of their high thermal conductivity, high chemical reactivity and high modulus of elasticity. (Richard et al., 2001).

Widely used cutting tools in machining these materials are solid carbide in earlier days and now coated carbide are used. In order to improve tool life, carbide tool coated with variety of materials were introduced more than a decade back. Coating materials were chosen to enhance chemical stability, oxidation resistance and thermal conductivity as these factors significantly affect their wear behavior in machining applications, but tool wear has not improved as it should be.

Usually, wear of coated carbide tools when machining mild steel increased when the substrate is exposed through the loss of the coating material. Subsequently loss of coating weakens the cutting tool, increases the forces used in cutting and causes a lack of consistency in material removal. Meanwhile, some researchers had investigated the effect of machining parameters on tool wear and tried to optimize machining parameters to minimize tool wear and to improve machineability. Those machining parameters are cutting speed, feed rate and depth of cut. In addition, tool wear is one of the most important parameters in the machining research area. Most researchers have dealt the effect of cutting variables on tool life by the one-variable-at-a-time method. This approach needs a separate set of tests for each combination of cutting condition and cutting tool. The approach required large amount of cost and cannot consider the combined effect of cutting conditions on response (Sundaram et al., 2008).

In this project, titanium nitride (TiN) coated carbide insert produced by Pramet Pvt. Ltd. will be tested for its performance in machining mild steel. For this research, the experiment will be performed by using pure mild steel and turning process by using Conventional Lathe machine will be performed to investigate tool wear which take account the combined effect of cutting variables using design of experiment including cutting speed, feed rate, and cutting length.

1.3 PROBLEM STATEMENT

Machineability of mild steel considered good although the cutting temperature is high. The characteristic of mild steel like high strength, high resistance to breakage and high modulus of elasticity has increased the tool wear of the coated carbide when it is used to machining the mild steel for long period. As a result, optimization of the parameters used when machining of mild steel still need to be improved. Study of tool wear is still need to be done in order reduce the tool wear of the coated carbide insert.

1.4 OBJECTIVE

The objectives of this project are:

(i) To investigate the progress of tool wear and determine the crater wear and flank wear of the tool in machining mild steel.
(ii) To determine the machining parameters that influence the tool wear.
(iii) To establish tool wear curves in machining mild steel.

1.5 PROJECT SCOPE

In order to achieve the objectives of the project, the following scopes are listed:

(i) Turning operation is done by using conventional lathe machine.
(ii) STATISTICA software is used to create the design of experiment (DOE) for this experiment.
(iii) Machining variables considered are cutting length, cutting speed and feed rate.
(iv) The independent variables will be varied up to three levels. The cutting speed, Vc used are 90, 120 and 150 m/min, feed rate, f used are 0.05, 0.10 and 0.15 mm/rev and the cutting length, L used are 60, 120 and 180 mm.
(v) Flank and crater wear of the coated carbide inserts will be investigated and measured by using optical microscope with Image Analyzer.
(vi) Flank wear and crater wear curves will be plotted in Minitab Software.

1.6 SUMMARY

Chapter 1 discussed generally about project background, problems statement, objectives and scopes of the project in order to complete the investigation of wear of coated carbide insert in machining of mild steel. This chapter is a fundamental for this project and as a guideline to complete this project research.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter will introduce and explain about the mild steel, including types of carbon steel available in the market and machineability of mild steel. Then types of tool material and its geometry will be explained. Next, the literature review of the coated carbide insert and types of coated carbide insert will be discussed. Finally the types of tool wear occurred in the inserts, stages of tool wear and the effects of tool wear on performance measurement will be included in this chapter.

2.2 CARBON STEEL

Carbon steels generally are classified by their proportion (by weight) of carbon content. They are classified by three major categories, which are low-carbon steel, medium-carbon steel and high-carbon steel (Kalpakjian et al., 2006).

2.2.1 Low Carbon Steel

Low carbon steel, also known as mild steel, contains 0.05 % to 0.26 % of carbon (e.g. AISI 1018, AISI 1020 steel). These steels are ductile and have properties similar to iron. They are cheap, but engineering applications are restricted to non-critical components and general paneling and fabrication work. These steels cannot be effectively heat treated. Consequently, there are usually no problems associated with heat affected zones in welding process.

The surface properties can be enhanced by carburizing and then heat treating the carbon-rich surface. High ductility characteristic results in poor machinability (Kalpakjian et al., 2006).

2.2.2 Medium Carbon Steel

Medium carbon steel contains 0.29 % to 0.54 % of carbon (e.g. AISI 1040, AISI 1045 steel). These steels are highly susceptible to thermal treatments and work hardening. They easily flame harden and can be treated and worked to yield high tensile strengths provided that low ductility can be tolerated. The corrosion resistance of these steels is similar to low carbon steel, although small additions of copper can lead to significant improvements when weathering performance is important. Medium carbon steels are still cheap on market and command mass production. They are general purpose but can be specified for use in stressed applications such as rails and rail products, couplings, crankshafts, axles, bolts, rods, gears, forgings, tubes, plates and constructional steel (Kalpakjian et al., 2006).

2.2.3 High Carbon Steel

High carbon steel contains 0.55 % to 0.95 % carbon (e.g. AISI 1086, AISI 1090). Cold working is not possible with any of these steels, as they fracture at very low elongation. They are highly sensitive to thermal treatments. Machinability is good, although their hardness requires machining in the normalized condition. Welding is not recommended and these steels must not be subjected to impact loading. They are normally used for components that require high hardness such as cutting tools and blades (Kalpakjian et al., 2006).

2.3 LATHE MACHINE

Lathes are generally considered as the oldest machine tools. Wood-working lathes originally were developed during the period 1000-1001 B.C. However metalworking lathes with leadscrew were only built during late 1700s. The most common laths originally was called an engine lathes, because it was powered with overhead pulleys and belts from nearby engines on the factory floor. Today, these lathes are all equipped with individual electric motors (Kalpakjian et al., 2006).

Lathe machine is considered as the backbone of machine shop, and a through knowledge of it is essential for machinist. Lathe machine is a machine which work is held so that it can be rotated about an axis while the cutting tool is traversed past the work from one end to the other thereby forming it to the required shape (Stephenson et al., 1997).

Common operations performed on a lathe are: facing, parallel turning, taper turning, knurling, thread cutting, drilling, reaming, and boring. The spindle is the part of the lathe that rotates. Various workholding attachments such as three jaw chucks, collets, and centers can be held in the spindle. The spindle is driven by an electric motor through a system of belt drives and/or gear trains. Spindle speed is controlled by varying the geometry of the drive train. The main function of lathe is to provide a means of rotating a workpiece against a cutting tool, thereby removing metal. All lathes, regardless of size and design are basically the same and serve 3 functions:

(i) A support for the lathe accessories or the workpiece
(ii) A way of holding and revolving the workpiece
(iii) A means of holding and moving the cutting tool

Size of the engine lathe is determined by the max diameter of work which may be revolved or swung over the bed, and the longest part that can be held between lathe centers. Lathes found in training programs generally have swing of 9.0 to 13.0 in (230-330 mm) and bed length from 20.0 to 60.0 in (500-1500 mm). Lathes used in industry may be much larger, doubling in swing and capacity. Bed is a heavy rugged casting made to support the working parts of the lathe. On its top section are major parts of lathe. Commonly, lathes are made with flame-hardened and ground ways to reduce wear and to maintain accuracy (Stephenson et al., 1997).

Headstock is attached to the left side of the bed. The headstock spindle is a hollow cylindrical shaft supported by bearing. It provides a drive from the motor to workholding devices. Live center, sleeve, face plate or a chuck can be fitted to the spindle nose to hold and drive the work. The live center has spaces that provides a bearing surface for the work to turn between centers. Most modern lathes are geared-head and the spindle is driven by series of gears in the headstock. Through a series of levers, different gears can be engaged to set various spindle speeds for different types of sizes of work. The types of speed-change levers or controls used on each lathe machine are varying, depending on the manufacturers. The feed-reverse lever can be place in three positions. One position provides forward direction; the center position is neutral while the other position reverses the feed rod direction and leadscrew (Stephenson et al., 1997).

Tailstock is made up of two units. The top half can be adjusted on the base by two adjusting screws for aligning the tailstock and headstock center for parallel turning. These screws can also be used to offset the tailstock for taper turning between centers. Tailstock can be lock at any position along the bed of lathe by clamping the lever or tighten the nut (Stephenson et al., 1997).

At one end of dead center is tapered to fit into the tailstock spindle, while the other end has spaces to provide a bearing support for work turned between the centers. A spindle-binding-lever or lock handle is used to hold the tailstock spindle in a fixed position. The tailstock handwheel moves the spindle in and out of the tailstock casting. It can also use to provide a hand feed for drilling and reaming operation.

2.3.1 Operations That Can Be Done Using Lathe Machine

Turning is one of the general machining processes. That is, the part is rotated while a single point cutting tool is moved parallel to the axis of rotation. Turning can be done either on the external or internal surface of the part. It is to produce straight, conical, curved, or grooved workpieces. Following are some of the operations that can be done using Lathe Machine:

(i) Facing is part of the turning process. It is to produce a flat surface at the end of the part and perpendicular to its axis. It is useful for parts that are assembled with other components.

(ii) Parting is also called cutting off. It is used to create deep grooves which will remove a completed or part-complete component from its parent stock into discrete products.

(iii) Grooving is like parting, except that grooves are cut to a specific depth by a form tool instead of severing a completed/part-complete component from the stock. Grooving can be performed on internal and external surfaces, as well as on the face of the part.

(iv) Drilling is used to remove material from the inside of a workpiece, producing a hole. It may follow by boring to improve its dimensional accuracy and surface finish.

2.3.2 Turning of Low-Carbon-Steels

As the steel progressively deformed, microvoids starts to form at the ferrite grain boundaries and at any inclusions that present. Turning of low-carbon steels produce long chips. Built-up edge will form on an indexable insert if a chipbreaker doesn't create a sufficient shear angle to curl the chip away from the insert's rake face. Low cutting speed is another cause of built up edge, (BUE) which acts as an extension of the cutting tool, changing part dimensions and imparting rough surface finishes. When that is the case, the cutting speed should be increased 15 to 20 percent or more until the surface finish improves (Isakov et al., 2007).

2.4 CUTTING TOOL

Cutting tool is any tool that is used to remove metal from the workpiece by means of shear deformation and they are generally made of tool steels. The selection of cutting-tool materials for a particular application is among the most important factors in machining operations. The cutting tool is subjected to 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 following characteristics (Kalpakjian et al., 2006):

(i) Hot hardness:
The hardness, strength, and wear resistance of the tool are maintained at the temperatures encountered in machining operations. This ensures that the tool does not undergo any plastic deformation and, thus, retains its shape and sharpness.

(ii) Toughness and impact strength (mechanical shock):
Impact forces on the tool encountered repeatedly in interrupted cutting operations (such milling, turning on a lathe, or due to vibration and chatter during machining) do not chip or fracture the tool.

(iii) Thermal shock resistance:
To withstand the rapid temperature cycling encountered in interrupted cutting.

(iv) Wear resistance:

An acceptable tool life is obtained before the tool has to be replaced.

(v) Chemical stability and inertness:

With respect to the material being machined, to avoid or minimize any adverse reactions, adhesion, and tool–chip diffusion that would contribute to tool wear.

2.4.1 Tool Material

Various cutting tool materials with a wide range of mechanical, physical, and chemical properties have been developed over the years. The desirable tool-material characteristics are chosen based on the criteria below:

(i) Hardness and strength are important with regard to the hardness and strength of the workpiece material to be machined.

(ii) Impact strength is important in making interrupted cuts in machining, such as milling.

(iii) Melting temperature of the tool material is important versus the temperatures developed in the cutting zone.

(iv) The physical properties of thermal conductivity and coefficient of thermal expansion are important in determining the resistance of the tool materials to thermal fatigue and shock.

Tool materials generally are divided into the following categories, including:

(i) High-speed steels
(ii) Cast-cobalt alloys
(iii) Carbides
(iv) Coated tools
(v) Alumina-based ceramics
(vi) Cubic boron nitride
(vii) Silicon-nitride-based ceramics
(viii) Diamond
(ix) Whisker-reinforced materials and nanomaterials