UNIVERSITI TEKNIKAL MALAYSIA MELAKA

INVESTIGATION OF TOOL WEAR WHEN MACHINING AISI 1045 USING UNCOATED CARBIDE CUTTING TOOL

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

(Manufacturing Process) (Hons.)

by

LLM LIYEN

B051210109

920710-01-5496

FACULTY OF MANUFACTURING ENGINEERING

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ABSTRAK

Projek ini membentangkan hasil kajian yang telah dilakukan ke atas prestasi pemesinan mata alat karbida yang tidak bersalut dengan kelajuan pemotongan yang berbeza dan keadaan. Kesan kelajuan dan kadar suapan memotong telah dikenal pasti berdasarkan perbandingan antara trend kehausan pada mata alat dan mekanisme kehausan untuk keadaan pemesinan kering dan basah. Bahan kerja yang dipilih dalam projek ini adalah AISI 1045 dianggap sebagai keluli karbon sederhana. Alat pemotongan telah menjalani pemesinan oleh mesin pelarik CNC dan kemudian dianalisis untuk mengkaji prestasi mereka. Dua parameter telah diubahsuaikan iaitu kelajuan pemotongan dan kadar suapan. Kedalaman potongan adalah tetap untuk semua keadaan latar. Pada keadaan pemotongan, ciri-ciri prestasi yang diukur termasuk haus pada mata alat dan kasar pemukaan. Mikroskop imbasan elektron (SEM) dan mikroskop stereo (SM) telah digunakan untuk memeriksa kehausan pada mata alat dan mekanisme kehausan. Daripada analisis, keputusan menunjukkan bahawa kehausan mata alat berlaku pada kedua-dua keadaan memotong. Walau bagaimanapun, pemotongan dalam keadaan basah mempunyai prestasi yang lebih baik berbanding pemotongan keadaan kering. Penggunaan penyejuk boleh diabaikan apabila pemesinan AISI 1045 pada kadar suapan yang lebih tinggi. Kajian ini menunjukkan bahawa peningkatan kelajuan pemotongan dan kadar suapan akan meningkatkan kadar kehausan alat pada kedua-dua keadaan.

ABSTRACT

This project presents the experimental investigation that was done on the machining performance of uncoated carbide cutting tools on different cutting speed and condition. Effect of cutting speed and feed rate were identified based on the comparison of the tool wear trend and wear mechanism for both dry and wet machining conditions. The workpiece materials selected in this project was AISI 1045 considered as medium carbon steel. The cutting tools were undergone machining by CNC lathe machine and then have been analyzed in order to study their performance. Two parameters were varied which were cutting speed and feed rate. The depth of cut was kept constant for all the setting conditions. At the above cutting conditions, the performance characteristics measured were the tool wear. A scanning electron microscopy (SEM) and stereo microscope (SM) has been used to examine the tool wear and wear mechanism. From the analysis, result showed that tool wear occurred for both cutting conditions. However, wet cutting performed better as compared to dry cutting. The use of coolant demonstrated a negligible effect when machining AISI 1045 at higher feed rate. This study shows that increase of cutting speed and feed rate will increase tool wear of cutting tool at both conditions.

DEDICATION

Specially dedicated to my beloved family, project supervisor and all my friends that encouraged me throughout my journey of education.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

AISI - American Iron and Steel Institute

BUE - Build up Edge

CNC - Computer Numerical Control

DOC - Depth of Cut

DOE - Design of Experiment

HSS - High Speed Steel

ISO - International Organization of Standardization

MRR - Material Removal Rate

MQL - Minimum Quantity Lubrication

SM - Stereo Microscope

SEM - Scanning Electron Microscope

WC - Tungsten Carbide

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Machining is a process to produce the components part by removing the material into required shape. These processes apply in major industrial practice such as automotive and aerospace. There are three major factors that contributed to efficiency of machining which are cutting tools, workpiece material and cutting parameters.

For machining, AISI 1045 considered as medium carbon steel that widely used in manufacturing industries, especially in automotive because of its mechanical behaviour such as good machinability, high strength and impact properties in either the normalized or hot rolled condition (Ellison, 2015). AISI 1045 steel has been trending for machining material in nowadays and its application in manufacturing industry are increasing due to its properties (Thangarasu and Sivasubramanian, 2012). In recent years, there has been increasing interests in research of machinability AISI 1045 steel that concentrate to reduce manufacturing cost and increase productivity (Kishawy *et al*, 2011).

Recently developments in the manufacturing industry aim to produce high quality products with reduced time and cost. Automated and flexible manufacturing systems such as the computerized numerical control (CNC) machines are employed due to the capable of minimizing the processing time while achieving high accuracy. Turning process is one of the most used methods for cutting and the finishing of machined parts. In this process, it is vital to select input (cutting) parameters with great precision for achieving high cutting performance (A. Qasim *et al*, 2015).

The significant use of high cutting velocity and feed rate are increasing in order to have high machining productivity. Furthermore machining essentially will produces high cutting temperature, which not only reduces tool life, but also affect the product quality. Tool wear is a natural occurrence in all machining processes and can lead to tool failure. High performance cutting tools that have high strength, high toughness and high hardness, are required to machine these materials effectively and safely (Azuan, 2013; Khan *et al*, 2009).

For that reason, tool wear is an important parameter for machining AISI 1045 because it is a significant factor that affects productivity and manufacturing efficiency. In response tool wear of carbide cutting tool are being subject of interest to study their behaviour when machining on AISI 1045 under dry and wet condition. However, research has consistently shown that tool wear are the consequence of the load, friction, and high temperature between the edge of cutting and the work piece. The major causes of tool wear are mechanical, thermal, chemical and abrasion. The cyclic mechanical forces cause fatigue on the tool cutting edge. The temperature of a tool increases as the cutting speed increases (Gu *et al*, 2010).

More recently, literature has emerged that offers contradictory findings about machining condition of cutting tools. This is because when machining on wet condition it will produce longer tool life due to low friction and temperature (Kalpakjian, 2013). However, due to strict environmental regulations, coolants are a major source of pollution from the machining industry. On the other hand, the management and disposal of cutting fluids must follow rules of environmental guideline. This is because the worker may be affected by the bad effects of cutting fluids, such as by the skin and complications of breathing on the shop floor (Mazurkiewicz *et al*, 2009). The demand for environmentally sustainable manufacturing is the primary drivers for technology that reduces the use of liquid coolant and dry cutting condition is introduced in order to solve the problem.

Several studies have shown that tool wears are primarily happening due to abrasion at lower speed condition. When cutting speed is higher, the tool rake face temperature will rise consequently. This temperature can further increase on dry machining condition. This is due to the important deformation associated with large shear strains in the primary shear zone and to the friction effects along the tool chip interface (Moufki, 2008).

This project investigates tool wear of carbide cutting tools when machining AISI 1045 steels on wet and dry condition with varying cutting speed. In this research, the evaluation of machining performance of the cutting tools depends on the tool wear and wear mechanism. The methodology used in this project is experimental procedures. By referring to an experiment that will be done, the tools must undergo a machining test at various cutting condition before analysis is done with tool. The evaluation of this research will be examined using a stereo microscope (SM) and scanning electron microscopes (SEM).

1.2 Problem Statement

In industry, machining operation such as turning, milling, drilling and grinding commonly use especially in manufacturing industry. There is a need to produce high volumes of product in order to ensure their companies always achieve their target. The optimization of machining process for the achievement of high responsiveness of production is the key factor. However, it can cause wear on cutting tool which is a result of physical contact between cutting tool and workpiece that remove small parts of the material from cutting tool. Tool wear can cause catastrophic failure of the tool that causes significant damage to the workpiece and even to machine tool after a certain limit. As getting inspiration from this kind of situations, this project consist the research of the tool wear and in the meantime includes the investigation of wear mechanism. It is necessary to compare the cutting performance in both cases of wet and dry cutting to know which techniques are better to machine AISI 1045.

1.3 Objectives

(a) To identify the effects of cutting speeds and feed rate on tool wear of carbide cutting tools during machining AISI 1045 Steel at dry and wet condition.
(b) To analyze the type of wear mechanisms during machining AISI 1045 Steel at dry and wet conditions.
(c) To compare the performance of tool wear under dry and wet machining.

1.4 Scope of Study

The scopes of this research aim to conduct machining process on AISI 1045 by using carbide cutting tools. In this project, the selected process is turning which will be performed by using CNC turning machine, the varying parameter is cutting speed and feed rate while depth of cut and cutting time are kept constant. The performance measures to be evaluated are tool wear and wear mechanisms of the cutting tools. The cutting tool used in this experiment is carbide cutting tool. Tool wear of carbide insert will be analyzed by using Stereo Microscope and Scanning Electron Microscopy (SEM).

CHAPTER 2

LITERATURE REVIEW

The literature review is one of the scope studies which is locating and summarizing the studies about the topic. It will provide part information in order to get the whole data about CNC lathe machine, cutting tools and workpiece material. This chapter presents related study done by previous research on the tool wear, tool life and wear mechanisms. The purpose of this chapter is to gather the information that could contribute to this project.

2.1 Metal Machining

Over a year manufacturing industry has become one of most growth industries this day. Many manufactured products required machining at some of their stage production. Machining can be defined as the removal of unwanted material from the work piece into a finish product of the desired shape, size and surface quality. According to El-Hofy (2011), the evolution of new cutting tool material opened a new evolution for the machining industry where machine tool development took place. There are several classifications of machining process, one of it is machining by cutting and the common process is turning, cutting off, slab milling and end milling. The primary components of the typical metal cutting process are tools, work piece and the machine tool as shown in Figure 2.1.

2.1.1 Machining Element

According to Kalpakjian and Schmid (2013), there are several primary elements in the following below that are required for a machining process.

Table 2.1: Primary element of machining (Kalpakjian & Schmid, 2013)

Workpiece	Its shape and size for continuous and intermittent cutting, the chemical composition, mechanical properties and metallurgical properties.
Tool	Material and geometry
Chip	Types of chips and their geometry
Cutting fluid	Its chemical composition, rate of flow and the mode of application.

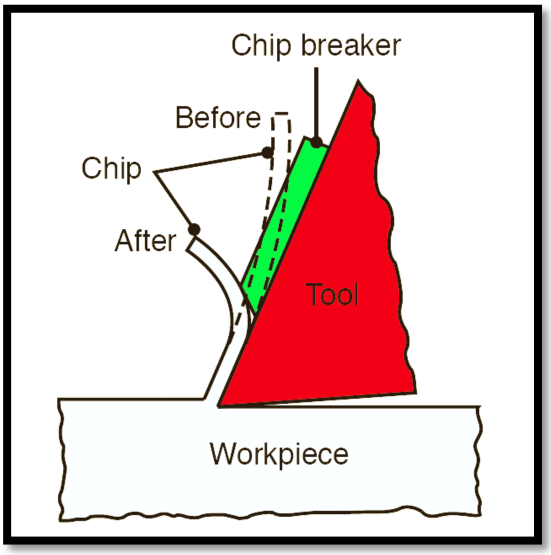


Figure 2.1: Cutting Process (Kalpakjian & Schmid, 2013)

2.2 Mechanic of Cutting

The cutting process can be influenced by several factors which are independent variable and dependent variable. Table 2.2 shows the factors that influence machining operations.

Table 2.2: Factors influencing machining operations (Kalpakjian and Schmid, 2013)

Parameter	Influence and interrelationship
Machinability	Related to tool life, surface finish and forces
High Temperature	Influences crater wear and dimensional accuracy of the work part; may cause thermal damage to work piece surface.
Tool wear	Influences surface finish and integrity, dimensional accuracy, temperature rise, forces and power.
Cutting speed, depth of cut, feed and cutting fluid.	Forces, power, temperature rise, tool life, type of chip, surface finish and integrity.
Tool angles	Related to chip flow direction, resistance to tool wear and chipping.
Continuous chip	Good surface finish and steady cutting force especially in automated machinery.
Discontinuous chip	Desirable for ease of chip disposal; fluctuating cutting forces can affect surface finish and cause vibration and chatter.
Built up edge	Poor surface finish and integrity; if thin and stable, edge can protect tool surfaces.

2.3 Turning Process

Turning is a method of machining by cutting the workpiece carried out the main rotary motion while the tool performs the linear motion. There are two types of motion in turning which is primary motion and auxiliary motion. Major motion is the rotary motion of the workpiece around the turning axis, while auxiliary motion is feed motion or the linear motion of the tool (Helmi and El-Hofy, 2011). Turning processes can be categorized according to the direction of tool feed. There are three common types in turning processes. First is straight turning, happens when the direction of the feed motion is parallel to the turning axis. Second taper turning, which is occurring when the direction of the tool feed motion intersect with the turning axis. Figure 2.2 shows a various operation that is performed by lathe machine as mention above. Lathe machine is known widely as versatile machine that capable to produce various cutting shapes and process.

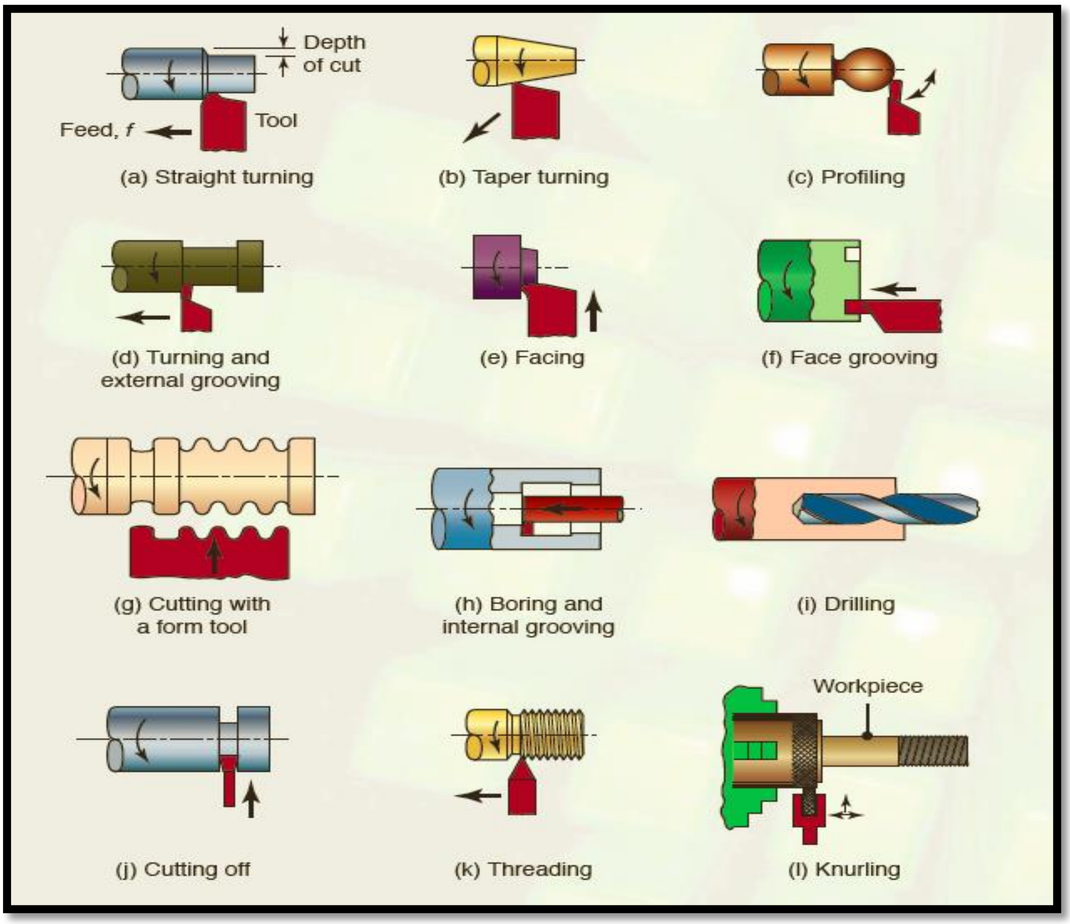


Figure 2.2: The turning process (Kalpakjian and Schmid, 2013)

2.4 Turning Process Parameters

According to Arthur *et al* (2012), process parameter has a direct influence on machining process and it is important to control these parameters to get optimized productivity. Turning process parameters such as tool geometry, cutting speed and depth of cut are important to control in order to get better finishing product with low cost and high productivity.

2.4.1 Tool geometry

Kalpakjian and Schmid (2013) state that in a single point cutting tool various angle plays a significant function in machining operations. These angles are measured in a coordinate system consisting of the three major axes of the tool shank. Nonetheless, these angles may be dissimilar with regard to the workpiece, after the tool is mounted in the tool holder. There are about five types of angle influence in tool geometry.

(a) Rake angle

Rake angle is significant in holding both the way of chip flow and the strength of the tool tip. Positive rake angles can reduce forces and temperatures plus improve the cutting performance. Nonetheless, positive angles also result in a small included angle of the tool tip possibly leading to premature tool chipping and failure, depending on the toughness of the tool material.

(b) Side rake angle

Side rake angle generally controls the direction of chip flow and more important than the back rake angle. Typical angle for machining carbide inserts are in the range from -5° to 5°.

(c) Cutting edge angle

Cutting force, chip formation and tool strength are affected by this angle.

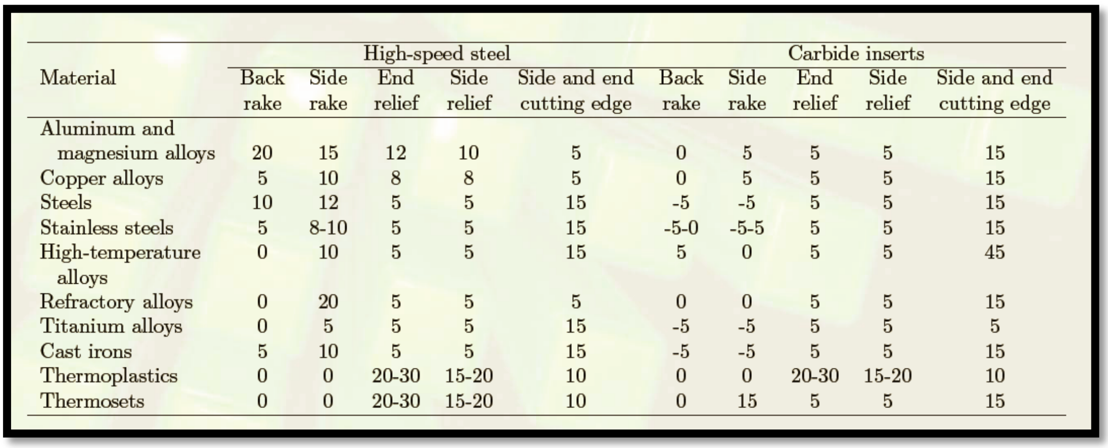
(d) Relief angle

Controls interference and rubbing at the tool workpiece interface. If it is excessively large, the tool tip may chip off; if it is excessively small, flank wear may be unreasonable.

(e) Nose radius

Tool tip strength and surface finish affect by nose radius. The smaller the sharp tool, the rougher the surfaces finish of the workpiece and the lower the strength of the tool. Nevertheless, large nose radii can lead to tool chatter.

Figure 2.3 shown recommended tool geometry for turning process for various workpiece materials.



Material	High-speed steel					Carbide inserts				
	Back rake	Side rake	End relief	Side relief	Side and end cutting edge	Back rake	Side rake	End relief	Side relief	Side and end cutting edge
Aluminum and magnesium alloys	20	15	12	10	5	0	5	5	5	15
Copper alloys	5	10	8	8	5	0	5	5	5	15
Steels	10	12	5	5	15	-5	-5	5	5	15
Stainless steels	5	8-10	5	5	15	-5-0	-5-5	5	5	15
High-temperature alloys	0	10	5	5	15	5	0	5	5	45
Refractory alloys	0	20	5	5	5	0	0	5	5	15
Titanium alloys	0	5	5	5	15	-5	-5	5	5	5
Cast irons	5	10	5	5	15	-5	-5	5	5	15
Thermoplastics	0	0	20-30	15-20	10	0	0	20-30	15-20	10
Thermosets	0	0	20-30	15-20	10	0	15	5	5	15

Figure 2.3: Recommendations for Tool Angles in Turning (Kalpakjian & Schmid, 2013)

2.4.2 Material Removal Rate

In turning process material removal rate can be defined as the volume of material removed per unit time with the unit of mm^3/min. Below are basic formula for material removal rate (MRR) and summary of turning parameter and formula are shown in Table 2.3.

$$MRR = \pi D_{avg} dfN \qquad \text{Eq 1}$$

Where,

$$D_{avg} = \frac{Do+D_f}{2} \qquad \text{Eq 2}$$

It also can be,

$$MRR = dfV \qquad \text{Eq 3}$$

Where

$$t = \frac{1}{fN} \qquad \text{Eq 4}$$

Table 2.3: Formula for turning parameters (Kalpakjian & Schmid, 2013)

Symbol	**Description**
N	Rotational speed of workpiece, rpm
f	Feed, mm/rev
υ	Feed rate or linear speed of the tool along workpiece length, mm/min
V	Surface speed of workpiece, m/min
l	Length of cut, mm
D_o	Original diameter of workpiece, mm
D_f	Final diameter of workpiece, mm
D_{avg}	Average diameter of workpiece, mm
d	Depth of cut, mm
t	Cutting time, s or min
MRR	mm^3/min

2.4.3 Cutting Speed

The cutting speed can be determined by the rate at which a point on the circumference of the work passed the cutting tool. Cutting speed is expressed in meters per minute (m/min). Magd *et al*, (2012) mentions to get better production rate