UNIVERSITI TEKNIKAL MALAYSIA MELAKA

STUDY ON THE PARAMETERS EFFECT OF TOOL WEAR FOR DIFFERENT CUTTING TOOL IN TURNING PROCESS

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 “Study of the parameters effect of tool wear for different cutting tool in turning process” is the results of my own research except as cited in references.

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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. Mohd Rizal bin Salleh)
CHAPTER I
INTRODUCTION

1.1 BACKGROUND

Austenitic stainless steel is a material from the grades of chromium-nickel steels which exhibiting a very high corrosion resistance and excellent mechanical properties. Austenitic stainless steels cannot be hardened by traditional heat treatment processes but they can be strengthened by cold working (Novak, 1978). AISI 304 steel is hard to machine. Machining operations of austenitic stainless steels are usually accompanied by a number of difficulties such as irregular wear and Built-Up-Edge (BUE) on the tool flank face and crater face respectively. The present of BUE will cause an increasing in tool wear rate and deterioration of the surface integrity of the work. The poor machinability of this material is usually accounted for some reasons such as having very low heat conductivity, high ductility, high tensile strength, high fracture toughness and high work hardening rate (Groover, 1990).

Several studies on machining of austenitic stainless steels have been conducted in order to evaluate the performance of different cutting tool materials when cutting different grades of stainless steels (Nordin et al, 2006). Coated and uncoated carbide tools are widely used in the metal-working industry and provide the best alternative for most turning operation. When machining using carbide tools under conventional cutting conditions, the gradual wear on the flank and the rake faces is the main process by which cutting tools failed (Che Haron et al., 2001). Wear mechanism could be classified as
adhesion, abrasion, diffusion, oxidation and fatigue (Trent, 1991). Some authors affirm that the flank wear in carbide tools initially occurs due to abrasion as the wear progresses. High speed cutting always generates high temperature, which enhances diffusion and oxidation process of carbide tool (Venkatesh, 1980). The advantages of high speed machining are the ability to produce precise dimension, high productivity and good quality parts. Most of the heat generated was used to remove the chip while the temperature of cutting tools and work piece maintained at ambient temperature.

The quality of machined surface becomes more critical in view of very high demand to performance, lifetime and reliability. The components that used in automotive, aerospace and other industries were applied in highly stress and temperature. Hence, the surface integrity of machined component becomes more important because it could cause sudden fatigue failure. Therefore, further investigation in machined surface of hard steel components are highly required.

### 1.2 PROBLEM STATEMENT

Due to the demand for the shorter production times of manufacturing petrochemical components, the carbide tools is the one of the best tools to use for improving productivity and reducing production cost. The carbide cutter has been proven to slow down the wear phenomenon of the cutting tools. The increasing in tool life allows for less frequent tool changes, therefore increasing the batch sizes that could be manufactured and in turn, not only reducing manufacturing cost, but also reducing the setup time as well as the setup cost.

However, improving the performance of the metal cutting operations in the case of machining hard material is still a major problem. Mainly, manufacturers used carbide cutter, coated and uncoated in machining of hard material. These carbide and coated carbide tools cut about 3 to 5 times faster than high-speed steels. Each type of carbide
affects the cutting tool characteristics differently. However, the machinist doesn’t know which cutter is appropriate for hard machining operations.

1.3 OBJECTIVES

- To investigate the effect of cutting parameters (cutting speed, feed rate and depth of cut) to the wear of tool.
- To analyze the performance of the tool with different parameters given.
- To propose the best cutting tool that can be used in machining of stainless steel 304.

1.4 SCOPE OF THE PROJECT

This research is focusing on analyzing and comparing the coated and uncoated carbide insert in terms of cutting speed, feed rate, depth of cut and its effect to the wear of tools which contribute to the life of the cutting tool. The material that will be used is stainless steel. For this project, the machining operation is conducted with conventional lathe machine. In this study, the performance of the cutting tool is evaluated by considering the progression of tool wear until it reached the limit value. The work will involve the setting-up and running of machining operation using carbide cutting tools followed by detailed examination of the used tools by using Stereo Zoom Microscope. The tool wear that will be obtained during machining are examined and analyzed. From that, the machining performance of the cutting tool will be found out.
Toward the achievement of the objectives of the project, here is the outline of experimental that will be carried out to produce the result.

**Figure 1.1**: Work flow of the study
CHAPTER II
LITERATURE REVIEW

The literature review is conducted to achieve the objectives of this research. It including the information of carbide tools used in turning, wear observation during turning operations, and life of the cutting tools itself. All of this formation is served as the guidelines in the course of the study.

2.1 INTRODUCTION

Machining is a process designed to change the size, shape, and surface of a material through removal of materials that could be achieved by straining the material to fracture or by thermal evaporation. There are many kinds of machining operations, each of which is capable of generating a certain part geometry and surface texture.

In turning, a cutting tool with a single cutting edge is used to remove material from a rotating workpiece to generate a cylindrical shape. The speed motion in turning is provided by the rotating workpart, and the feed motion is achieved by the cutting tool moving slowly in a direction parallel to the axis of rotation of the workpiece.

A machining system consists of three components: machine tool, cutting tool, and workpiece (Bhattacharya, 1996).
2.2 PHYSIC AND MECHANIC OF METAL CUTTING

Cutting processes are often necessary in order to impart the desired surface finish and dimensional accuracy to component. To achieve a good result in cutting processes, physic and mechanic of metal cutting are emphasis. A large number of variables have significant influence on the mechanics of chip formation in cutting operations. Commonly observed chip types are continuous, built up edge, discontinuous and segmented.

2.2.1 Physic Metal Cutting

For the physic of metal cutting, several of types chip (chip formation) produced are observed because it significantly influences the surface finish of the workpiece and the overall cutting operation. Most of cutting operations such as turning and milling involves two or more cutting edges inclined at various angles to direction of the cut. However, the basic mechanism of cutting can be explained by analyzing cutting done with single cutting edge (Schneider, 1999).
2.2.1.1 Chip Formation

Metal cutting chips have been classified into three basic types (Steve and Albert, 1997):

a) Discontinuous or segmented
b) Continuous
c) Continuous with built up edge

a) Discontinuous or segmented

Discontinuous or segmented chips are produced when brittle metal such as cast iron and hard bronze are cut or when some ductile metals are cut under poor cutting conditions. As the point of the cutting tool contacts the metals, some compression occurs, and the chip begins flowing along the chip tool interface. As more stress is applied to brittle metal by cutting action, the metal compresses until it reaches a point where rupture occurs and the chip separates from the unmachined portion. Generally, as a result of these ruptures, a poor surface is produced on the workpiece (Schneider, 1999).

Machine vibration or tool chatter sometimes causes discontinuous chips to be produced when ductile metal is cut. The following conditions cause the discontinuous chip (Steve and Albert, 1997):
i) Brittle work material.
ii) Small rake angle on the cutting tool
iii) Large chip thickness
iv) Low cutting speed
v) Excessive machine chatter.

b) Continuous

![Illustration of continuous chip (Schneider, 1999).](image)

Continuous chip are usually formed with ductile materials at high cutting speed and high rake angles. The deformation of the material takes place along a narrow shear zone, the primary shear zone. Continuous chip may because of friction, develop a secondary shear zone at the tool-chip interface. The secondary zone becomes thicker as tool-chip friction increase.

The process of chip formation occurs in a single plane extending from the cutting tool to the unmachined work surface. Machine steel generally forms a continuous chip with little or no built up edge when machined with a cemented carbide cutting tool or high speed steel toolbit and cutting fluid. To reduce the amount of resistance occurring as the compressed chip slides along the chip-tool interface, a suitable rake angle is ground on the tool and cutting fluid is used during the cutting operation. The conditions to producing a continuous chip are:
(a) Ductile work material
(b) Small chip thickness (relatively fine feeds)
(c) Sharp cutting tool angle
(d) A large rake angle on the cutting tool
(e) High cutting speed
(f) Cutting tool and work kept cool by use of cutting fluids
(g) A minimum of resistance to chip flow by:

i. A high polish on the cutting tool face
ii. Use of cutting fluids to prevent the formation of a built up edge
iii. Use of cutting tool material such as cemented carbide, which have a low coefficient of friction.

c) Continuous with built up edge

Figure 2.4: Illustration of continuous with built up edge (Schneider, 1999).

Continuous with built up edge is generated when cut low carbon machine steel and many high carbon alloyed steel at a low cutting speed with a high speed steel cutting tool and without the use of cutting fluids. The metal ahead of the cutting tool is compressed and forms a chip, which begins to flow along the chip tool interface. As result of the high temperature, high pressure, and high frictional resistance against the
flow of chip along the chip tool interface, small particles of metal begin adhering to the 
edge of the cutting tool while the chip shear away.

As the cutting process continues, more particles adhere to the cutting tool, a larger 
builtup results, which affects the cutting action. The continuous chip with built up edge, 
as well as being the main cause of surface roughness, also shortens cutting tool life. 
When a cutting tool starts to dull, it creates a compressing action on the workpiece, 
which generally produced work hardened surface. These types of chip affect cutting tool 
life in two ways:

(a) The fragments of the built up edge abrade the tool flanks as they escape with the 
workpiece and chip.
(b) A cratering effect is caused a short distance back from the cutting edge where the 
chip contacts the tool face. As this cratering continues, it eventually extends 
closer to the cutting edge until fracture or breakdown occurs.

The factors responsible for continuous built up edge are:
   (a) Ductile material
   (b) Coarse feed
   (c) Small rake angle
   (d) Low cutting speed
   (e) Dull cutting edge
   (f) Insufficient cutting fluid
   (g) High friction at chip tool interface

According to the Seah et al (1995), it shows that chip formation is affected when coolant 
is applied during a machining operation. The chip curl changes with the temperature 
gradient along the thickness of the chip. The direction from which the cutting fluid is 
applied is therefore an important factor affecting chip curl. Chip curl affects the size of 
the crater and the strength of the tool cutting edge.
The two main parameters influencing the chip morphology are the hardness of material and the cutting speed. That shows that the effect of the cutting speed and the hardness are interdependent; in fact, the chip formation is governed by more global physical quantity such as the generated energy, and by the consequent temperature. The chip formation mechanism based on the occurrence of a crack concerns very hard steels on account of their higher brittleness. Chip formation by cracking may occur with less hard steels but at higher cutting speeds, the embrittlement being induced by the kinetic of loading.

2.2.2 Mechanics Metal Cutting

In general, machining is 3D-process for providing an understanding of mechanics of machining; the process is simplified into a 2D-process called as Orthogonal Cutting as shown in Figure 2.5. In orthogonal cutting, the workpiece is a flat plate (it can be a thin tube too) and is machined using a wedge-shaped tool with a rake angle of $\alpha$ and a relief angle of $\sigma$. The workpiece is moving at a cutting speed of $V$ with a depth of cut to remove material. The width remains unaffected. An analysis based on the classical thin zone mechanics for materials that yield continuous chip with planar shear process (Merchant, 1989). The following assumptions were made:

i. The tool tip is sharp and no rubbing or ploughing occurs between the tool and workpiece.

ii. Plain strain conditions, such as there is no side spread and therefore the deformation is two dimensional.

iii. The stresses on the shear plane are uniformly distributed.
The resultant force on the chip applied at the shear plane is equal, opposite and collinear to the force applied which is the force applied to the chip at the tool-chip interface (Lapidge et al., 1997).

2.3 MACHINING PARAMETERS

For a metal cutting process, there are three variable considered as a parameter in machining which is speed, feed and depth of cut. Other factors such as kind of material and type of tool have a large influence in machining, but these three are the ones we can change by adjusting the controls, right at the machine. These three of variable is also importance in influence metal removal rate and tool life.

2.3.1 Speed

Speed is refers to the spindle and the workpiece. Rotating speed basically is stated in revolutions per minute (rpm). The importance figure for a particular turning operation is the surface speed, or the speed at which the workpiece material is moving past the cutting tool. It is simply the product of the rotating speeds times the circumference (in
feet) of the workpiece before the cut is started. It is expressed in surface feet per minute (sfpm), and it refers only to the workpiece. Every different diameter on a workpiece will have a different cutting speed, even though the rotating speed remains the same (Michigan Technological University’s Turning Information Center).

### 2.3.2 Feed

Feed is refers to the cutting tool, and it is the rate at which the tool advances along its cutting path. The feed rate is directly related to the spindle speed and is expressed in inches (of tool advance) per revolution (of spindle).

### 2.3.3 Depth of Cut

The term depth of cut means the stroke at which the cutting tool into a work material. Besides, depth of cut is mainly it is the thickness of layer being removed from the workpiece or the distance from the uncut surface of the work to the cut surface. The sectional area of chip is dependent upon feed and depth of cut. It is important to note that the diameter of the workpiece is reduced by two times the depth of cut because this layer is being removed from both sides of the work.
Below is a summary list of the terms used:

$D_a =$ initial diameter

$D_b =$ final diameter

$f_r =$ feed (in/rev, in/cycle, in/min, in/tooth)

$V =$ cutting speed

### 2.4 TOOL WEAR

Tool wear can be defined as the change of shape of the tool from its original shape, during cutting, resulting from the gradual loss of tool material.
Cutting tools are subjected to an extremely severe rubbing process. They are in metal to metal contact, between the chip and workpiece, under conditions of very high stress at high temperature. The situation is further aggravated due to the existence of extreme stress and temperature gradients near the surface of the tool. During cutting, cutting tools remove the material from the component to achieve the required shape, dimension and surface roughness. However, wears are occurring during the cutting action, and it will result in the failure of the cutting tool. When the tool wear reach certain extent, the tool or edge change has to be replaced to guarantee the ordinary cutting action.

### 2.5 TOOL WEAR PHENOMENA

![Tool wear phenomena](image.png)

In orthogonal and oblique cutting sections, the shear stress and normal stress involved in metal cutting is much higher than used in engineering mechanic. Due to the high contact stress between the tool rake face and the chip, it causes severe friction at the rake face as well as the friction between the flank and the machined surface. Hence result in all sort of wears which can be observed at rake face and flank face.
2.5.1 Crater wear (Rake Face Wear)

Crater wear occurred when chip flows away on the rake face, results in the severe friction between the chip and rake face, and leave a scar on the rake face which usually parallels to the major cutting edge. The crater wear could increase the working rake angle and reduce the cutting force, but it will also weaken the strength of the cutting edge. Crater wear on the chip face can be due to abrasive and diffusion wear mechanisms. The crater is formed through tool material being removed from chip face either by the hard particle grinding action or at the hottest part of the chip face through the diffusive action between the chip and tool material. Hardness, hot hardness and minimum affinity between materials minimize the tendency for crater wear. Excessive crater wear changes the geometry of the edge and can deteriorate chip formation, change cutting force directions and also weaken the edge.

![Figure 2.8: Crater wear (source: SANDVIK Coromant)](image)

2.5.2 Clearance (flank) Surface Wear

Wear on the flank (relief) face is called Flank wear and results in the formation of a wear land. Wear land formation is not always uniform along the major and minor cutting edges of the tool. Flank wear most commonly results from abrasive wear of the cutting edge against the machined surface and can be monitored in production by examining the
tool or by tracking the change in size of the tool or machined part. Flank wear can be measured by using the average and maximum wear land size $V_B$ and $V_{B\text{max}}$.

**Figure 2.9**: Flank wear (source: SANDVIK Coromant)

Flank wear takes place on the flanks of the cutting edge, mainly from the abrasive wear mechanism. The clearance sides which are leading, trailing and nose radius or parallel land are subjected to the workpiece when it moving past during and after chip formation. Flank wear and chipping will increase the friction, so that the total cutting force will increase. Flank wear will also affect the component dimensional accuracy. When form tool is used, flank wear will also change the shape of the component produced. In the end of flank wear, it will lead to poor surface texture, inaccuracy and increasing friction as the edge change shape.
2.5.2.1 Typical stage of tool wear in normal cutting situation

1. Initial wear region:

It is caused by micro-cracking, surface oxidation and carbon loss layer, as well as microroughness at the cutting tool tip in tool grinding (manufacturing). For the new cutting edge, due to the small contact area and high contact pressure, it will result in high wear rate. The initial wear size normally is $V_B = 0.05-0.1\text{mm}$

2. Steady wear region

After the initial (or preliminary) wear (cutting edge rounding), the micro-roughness improved, in this region, the wear size is proportional to the cutting time. The wear rate is relatively constant.
3. Severe wear:

When the wear size increases to a critical value, the surface roughness of the machined surface decreased. When the cutting force and temperature increase rapidly, the wear rate increases. Then the tool loses its cutting ability. In practice, this region of wear should be avoided.

2.5.3 Notch wear (Boundary Wear)

This is a special type of combined flank and rake face wear which occurs adjacent to the point where the major cutting edge intersects the work surface. The grooving at the outer edge of the wear land is an indication of a hard or abrasive skin on the work material. Such a skin may develop during the first machine pass over a forging, casting or hot-rolled workpiece. It is also common in machining of materials with high work-hardening characteristics, including many stainless steels and heat-resistant nickel or chromium alloys.

Figure 2.11: Notch wear (source: SANDVIK Coromant)
2.5.4 Chipping

Chipping of the tool, as the name implies, involves removal of relatively large discrete particles of tool material. Tools subjected to discontinuous cutting conditions are particularly intended to chipping. Built-up edge formation also has a tendency to promote tool chipping. A built-up edge is never completely stable, but it periodically breaks off. Each time some of the built-up material is removed it may take with it a lump (piece) of tool edge.

![Figure 2.11: Chipping of the cutting edge (source: SANDVIK Coromant)](image)

2.5.5 Plastic deformation

Plastic deformation takes place as a result of combined high temperatures and high pressure on the cutting edge. High speeds and feeds and hard workpiece materials mean heat and compression. For the tool material to stand up to this and not deform plastically, high hot hardness is critical. The typical bulging of the edge will lead to higher temperatures, geometry deformation, and chip flow changes until a critical stage is reached. The size of the edge rounding and cutting geometry also play a role in combating this wear type.