



**NATIONAL TECHNICAL UNIVERSITY COLLEGE OF
MALAYSIA**

**A Study of Surface Integrity Whilst Turning
AISI 1045 Steel with TiC/WC Coated Insert**

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

By

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KOLEJ UNIVERSITI TEKNIKAL KEBANGSAAN MALAYSIA
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JUDUL: A STUDY OF SURFACE INTEGRITY WHILST TURNING AISI 1045 STEEL WITH TIC/WC COATED TOOL

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ABSTRACT

This research is focused on the surface integrity of medium carbon machined by TiC/WC (Titanium Carbide coated) tool insert. The machining involved turning at high speeds using the computer numerical control (CNC) machine and without the presence of cutting fluid. The cutting speed was varied from 300m/min to 600m/min. The analysis of the surface integrity was conducted using Scanning Electron Microscope (SEM) and Axioskop (metallurgy) microscope. The surface roughness values of the samples were determined using Mitutoyo's surface tester. Highest value of surface roughness as determined by the Mitutoyo's surface tester was 3.11 μ m. With cutting speed 600m/min and machining time 12.5 minutes the highest surface roughness has produced. Therefore the lowest surface roughness was taken from 500m/min cutting speed and 7.5 minutes of machining. The value was 0.84 μ m. The result from the experiment showed that the surface roughness values increase with increasing tool wear. The TiC/WC inserts as used in this experiment were found able to produce good surface finish when used in high speed turning of AISI 1045. It produce good surface until it reach the machine parameter of 600m/min cutting speed and 12.5 minutes machining time.

DEDICATION

Specially dedicated to my beloved family especially my father (Mustapha Bin Bujang) and my mother (Razaah Bte Hossen); whose very concern, understanding, supporting and patient. Thanks for everything. To All My Friends, I also would like to say thanks.

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LIST OF SYMBOLS

V	Cutting Speed
π	3.142
D	workpiece diameter
N	Spindle Speed
$r.p.m$	Rotation per minutes
V_c	Chip velocity
F_c	Normal force
F_n	normal force opposite direction with F_c
F_r	radial force
f	Feed
Doc	Depth of cut
R_y	peak high
R_a	Average roughness
TiC	Titanium Carbide
WC	Tungsten Carbide

CHAPTER 1

INTRODUCTION

1.0 Project Background

The quality of a machined surface is becoming more and more important to satisfy the increasing demands of sophisticated component performance, longevity, and reliability. Structures for military and commercial aerospace, automotive, and other capital goods industries are being subjected to more severe conditions of stress, temperature, and hostile environments. In response to the above needs, there has been a continued increase in the development and use of heat resistant, corrosion resistant, and high strength alloys in the wide variety of structural applications. Many of the medium carbon hardness levels, are now being heat treated to very high strength levels for structural components.

When machining any component, it is first necessary to satisfy the surface integrity requirements. Surface integrity has two important parts. The first is surface texture, which governs principally surface roughness, which essentially is a measure of surface topography. This subject has been and being pursued by many investigators. The second is surface metallurgy which is a study of the nature of the surface layer produced in machining. Surface integrity of a surface produced by a metal removal operation includes the nature of both surface topography as well as surface metallurgy on the mechanical and physical properties of a material in its chosen environment. The name "surface integrity" was coined in 1964 and has since received growing attention in manufacturing circles both in the USA and around the world. (Field and Kahles 1964)

1.1 Objectives

The main objectives of this research are:-

- i. To study the relationship between the surfaces roughness values and turning parameters such as cutting speed and cutting time by machining medium carbon AISI 1045 with TiC/WC cutting tool under dry turning condition.
- ii. To analyzed the surface integrity of the material after the machining operation.
- iii. To study about another factor that maybe influences the surface roughness result in turning operation.

1.2 Scope of project

The scope of this project is to analyze the surface roughness of machined AISI 1045 perform CNC turning machine and coated cutting tool by variable cutting tool and cutting time. The surface roughness then measured by surface roughness tester and the surface integrity analyzed by Axioskop microscope and scanning g electron microscope (SEM). The result obtain from measurement and analyze are compare and the factor effect the result are researched.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Machining is the broad term used to describe removal of material from workpiece, covers several processes. These are usually divided into the following categories:

- Cutting, which is generally, involves single point or multipoint cutting tools, each with a cleared defined tool shape.
- Abrasive process such as grinding.
- Advanced machining process those utilize electrical, chemical, thermal, hydrodynamic method as well as lasers.

Turning is another of the basic machining processes. Turning produces solids of revolution which can be tightly tolerance because of the specialized nature of the operation. Turning is performed on a machine called a lathe in which the tool is stationary and the part is rotated. The figure below illustrates an engine lathe. Lathes are designed solely for turning operations, so that precise control of the cutting results in tight tolerances. The work piece is mounted on the chuck, which rotates relative to the stationary tool. (Kalpakjian 2005)

2.2 Machines, Equipments and Operations

2.21 Lathe machine

The engine lathe is a machine that is used to make round parts, or round features on parts of other shapes. All work on the engine lathe is done horizontally, with the workpiece rotating, in a counterclockwise direction in most cases. In woodturning, metalworking, metal spinning, and glassworking, a lathe is a machine tool which spins a block of material so that when abrasive, cutting, or deformation tools are applied to the block, it can be shaped to produce an object which has symmetry about an axis of rotation. Most suitably equipped metalworking lathes can also be used to produce most solids of rotation, plane surfaces and screw threads or helices. The material is held in place by either one or two centers, at least one of which can be moved horizontally to accommodate varying material lengths. Examples of objects that can be produced on a lathe include candlestick holders, cue sticks, table legs, bowls, baseball bats, crankshafts and camshafts. The basic mini-lathe operations are summarized as facing, turning, drilling, boring and threading.

In a metalworking lathe, metal is removed from the workpiece using a hardened cutting tool, which is usually fixed to a solid moveable mounting called the "toolpost", which is then moved against the workpiece using handwheels and/or computer controlled motors. The machine has been greatly modified for various applications however a familiarity with the basics shows the similarities between types. These machines consist of, at the least, a headstock, bed, carriage and tailstock. The better machines are solidly constructed with broad bearing surfaces (*slides* or *ways*) for stability and manufactured with great precision. This helps ensure the components manufactured on the machines can meet the required tolerances and repeatability required. The basic parts of lathe machine are:-

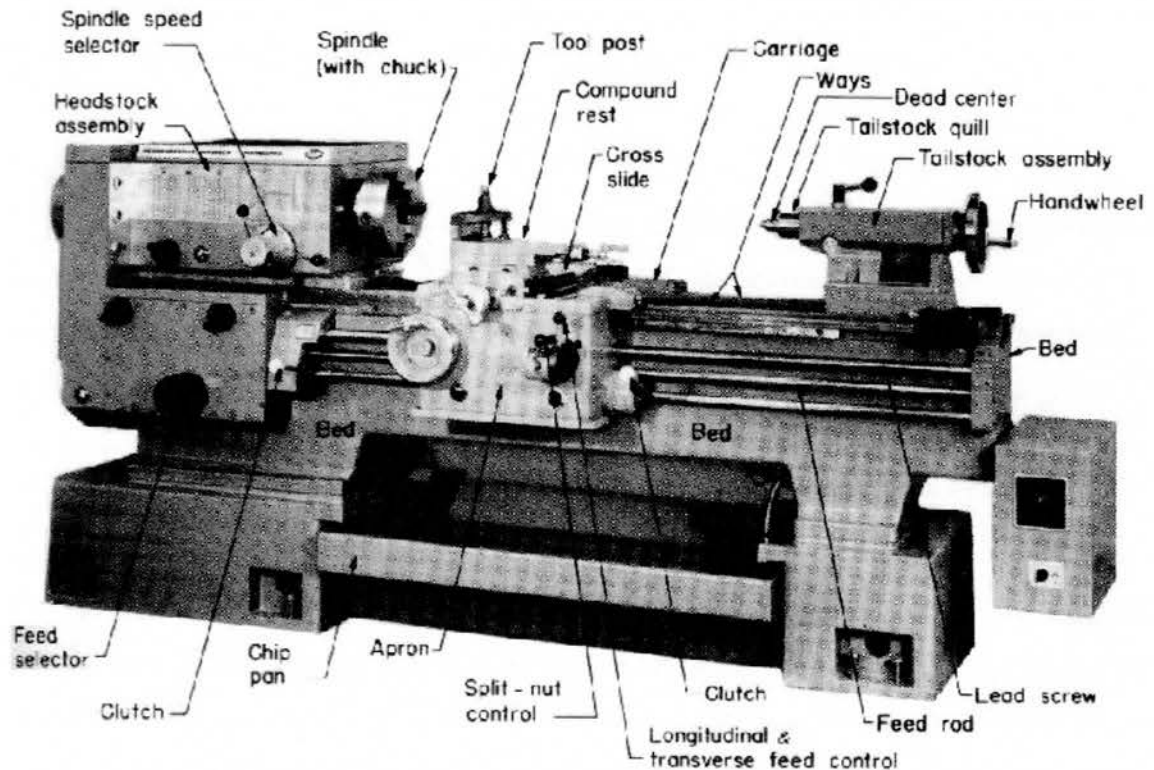


Figure 2.21: Lathe machine

i) Headstock

The headstock houses the main spindle, speed change mechanism, and change gears. The headstock is required to be made as robust as possible due to the cutting forces involved, which can distort a lightly built housing, and induce harmonic vibrations that will transfer through to the workpiece, reducing the quality of the finished workpiece.

The main spindle is generally hollow to allow long bars to extend through to the work area, this reduces preparation and waste of material. The spindle then runs in precision bearings and is fitted with some means of attaching work holding devices such as chucks or faceplates. This end of the spindle will also have an included taper, usually morse, to allow the insertion of tapers and centers. On older machines the spindle was directly driven by a flat belt pulley with the lower speeds available by manipulating the bull gear,

later machines use a gear box driven by a dedicated electric motor. The fully geared head allows the speed selection to be done entirely through the gearbox.

ii) **Bed**

The bed is a robust base that connects to the headstock and permits the carriage and tailstock to be aligned parallel with the axis of the spindle. This is facilitated by hardened and ground *ways* which restrain the carriage and tailstock in a set track. The carriage travels by means of a rack and pinion system, leadscrew of accurate pitch, or feedscrew.

iii) **Feed and lead screws**

The feedscrew is a long driveshaft that allows a series of gears to drive the carriage mechanisms. These gears are located in the apron of the carriage. Both the feedscrew and leadscrew are driven by either the change gears (on the quadrant) and or an intermediate gearbox (quick change gearbox). These intermediate gears allow the correct ratio and direction to be set for cutting threads or worm gears. Tumbler gears are provided between the spindle and gear train along with a quadrant plate that enables a gear train of the correct ratio and direction to be introduced. This provides a constant relationship between the numbers of turns the spindle makes, to the number of turns the leadscrew makes. This ratio allows screwthreads to be cut on the workpiece without the aid of a die. The leadscrew will be manufactured to either imperial or metric standards and will require a conversion ratio to be introduced to create thread forms from a different family. To accurately convert from one thread form to the other requires a 127-tooth gear, or on lathes not large enough to mount one, an approximation may be used. Multiples of 3 and 7 giving a ratio of 63:1 can be used to cut fairly loose threads. This conversion ratio is often built into quick change gearboxes.

iv) **Carriage**

In its simplest form the **carriage** holds the tool bit and moves it longitudinally (turning) or perpendicularly (facing) under the control of the operator. The operator moves the

carriage manually via the *handwheel* or automatically by *engaging* the feedscrew with the carriage feed mechanism, this provides some relief for the operator as the movement of the carriage becomes power assisted. The handwheels on the carriage and its related slides are usually calibrated, both for ease of use and to assist in making reproducible cuts.

v) Cross-slide

The cross-slide sits atop the carriage and has a leadscrew that travels perpendicular to the main spindle axis, this permits *facing* operations to be performed. This leadscrew can be engaged with the feedscrew (mentioned previously) to provide automated movement to the cross-slide, only one direction can be engaged at a time as an *interlock* mechanism will shut out the second gear train.

vi) Topslide

The tool bit is mounted in the toolpost which may be of the American *lantern* style, or in a turret type arrangement which can be manually rotated, between passes, to present a different position (and possibly tool) to the workpiece. Detachable tool blocks may be combined with this method and these allow the tool to be preset to a *center* height that will not change, even if the holder is removed from the machine.

vii) Tailstock

The tailstock is a toolholder directly mounted on the spindle axis, opposite the headstock. The spindle does not rotate but does travel longitudinally under the action of a leadscrew and handwheel. The spindle includes a taper to hold drill bits, centers and other tooling. The tailstock can be positioned along the bed and clamped in position as required. There is also provision to offset the tailstock from the spindles axis, this is useful for turning small tapers.

2.22 CNC lathe

CNC lathes are rapidly replacing the older production lathes (multispindle, etc) due to their ease of setting and operation. They are designed to use modern carbide tooling and fully utilize modern processes. The part may be designed by the Computer-aided manufacturing (CAM) process, the resulting file uploaded to the machine, and once set and trialled the machine will continue to turn out parts under the occasional supervision of an operator. The machine is controlled electronically via a computer menu style interface, the program may be modified and displayed at the machine, along with a simulated view of the process. The setter/operator needs a high level of skill to perform the process, however the knowledge base is broader compared to the older production machines where intimate knowledge of each machine was considered essential. These machines are often set and operated by the same person, where the operator will supervise a small number of machines (cell).

The design of a CNC lathe has evolved yet again however the basic principles and parts are still recognizable, the turret holds the tools and indexes them as needed. The machines are totally enclosed, due in large part to Occupational health and safety (OH&S) issues.



Figure 2.22: CNC lathe machine

The specific programmable functions:

2.22.1 Motion control

All CNC machine types share this commonality. They all have two or more programmable directions of motion called axis. An axis of motion can be linear (along a straight line) or rotary (along a circular path). One of the first specifications that imply a CNC machine's complexity is how many axes it has. Generally speaking, the more axes, the more complex the machine.

The axes of any CNC machine are required for the purpose of causing the motions needed for the manufacturing process. In the drilling example, these (3) axis would position the tool over the hole to be machined (in two axes) and machine the hole (with the third axis). Axes are named with letters. Common linear axis names are X, Y, and Z. Common rotary axis names are A, B, and C.

2.22.2 Programmable accessories

A CNC machine wouldn't be very helpful if all it could only move the work piece in two or more axes. Almost all CNC machines are programmable in several other ways. The specific CNC machine type has a lot to do with its appropriate programmable accessories. Again, any required function will be programmable on full-blown CNC machine tools. Here are some examples for one machine type.

2.22.3 Machining centers

- Automatic tool changer

Most machining centers can hold many tools in a tool magazine. When required, the required tool can be automatically placed in the spindle for machining.

- Spindle speed and activation

The spindle speed (in revolutions per minute) can be easily specified and the spindle can be turned on in a forward or reverse direction. It can also, of course, be turned off.

- Coolant

Many machining operations require coolant for lubrication and cooling purposes. Coolant can be turned on and off from within the machine cycle.

2.22.4 CNC programmed

A CNC program is nothing more than another kind of instruction set. It's written in sentence-like format and the control will execute it in sequential order, step by step. A special series of CNC *words* are used to communicate what the machine is intended to do. CNC words begin with letter addresses (like F for feed rate, S for spindle speed, and X, Y & Z for axis motion). When placed together in a logical method, a group of CNC words make up a command that resemble a sentence. For any given CNC machine type, there will only be about 40-50 words used on a regular basis. So if you compare learning to write CNC programs to learning a foreign language having only 50 words, it shouldn't seem overly difficult to learn CNC programming.

Program:

O0001 (Program number)

N005 G54 G90 S400 M03 (Select coordinate system, absolute mode, and turn spindle on CW at 400 RPM)

N010 G00 X1. Y1. (Rapid to XY location of first hole)

N015 G43 H01 Z.1 M08 (Instate tool length compensation, rapid in Z to clearance position above surface to drill, turn on coolant)

N020 G01 Z-1.25 F3.5 (Feed into first hole at 3.5 inches per minute)

N025 G00 Z.1 (Rapid back out of hole) N030 X2. (Rapid to second hole)

N035 G01 Z-1.25 (Feed into second hole)

N040 G00 Z.1 M09 (Rapid out of second hole, turn off coolant)

N045 G91 G28 Z0 (Return to reference position in Z)

N050 M30 (End of program command)