UNIVERSITI TEKNIKAL MALAYSIA MELAKA

INVESTIGATION OF SURFACE INTEGRITY WHEN MACHINING AISI 1045 USING UNCOATED CARBIDE CUTTING TOOLS

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

by

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DECLARATION

I hereby, declared this report entitled "Investigation of Surface Integrity When Machining AISI 1045 Using Uncoated Carbide Cutting Tools" is the results of my own research except as cited in references.

Signature   :   …………………………………………………………

Author's Name   :   SITI NUR RAHEENA BINTI HAMDAN

Date   :   22nd JUNE 2016

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) (Hons.). The member of the supervisory is as follow:

………………………………
(Project Supervisor)

ABSTRAK

Kertas kerja ini membentangkan penilaian kekasaran permukaan dan profil kekasaran apabila pemesinan keluli karbon di bawah keadaan basah dan kering dengan kelajuan pemotongan rendah dan tinggi. Bahan bahan kerja dan alat pemotong dipilih dalam kajian ini ialah AISI 1045 keluli karbon dan canela karbida. Alat memotong menjalani pemesinan ujian oleh CNC menjadikan operasi dan prestasi mereka dinilai oleh nilai kekasaran permukaan dan pemerhatian mengenai profil kekasaran permukaan. Ujian pemesinan telah diadakan di pelbagai kelajuan pemotongan 35 m/min hingga 53 m/min, kadar suapan ialah 0.15 mm/rev hingga 0.50 mm/rev dan kedalaman sama potong 1mm. Daripada analisis, didapati bahawa kekasaran permukaan meningkat kelajuan pemotongan meningkat pada kadar suapan yang lebih rendah daripada 0.15 mm rev. Sedangkan pada kadar suapan meningkat sebanyak 0.5 mm/rev, kekasaran permukaan menurun kelajuan pemotongan meningkat. Variasi kekasaran permukaan yang disyaki disebabkan oleh keadaan radius hidung, sama ada daripada penggunaan alat atau pembentukan tepi bangunan. Kajian ini membantu untuk memahami kesan kelajuan gelendong dan kadar suapan integriti permukaan apabila pemesinan AISI 1045 keluli karbon menggunakan alat pemotong karbida di bawah keadaan pemotongan basah.

ABSTRACT

This paper presents the evaluation of surface roughness and roughness profiles when machining carbon steel under wet and dry conditions with low and high cutting speeds. The workpiece materials and cutting tools selected in this research were AISI 1045 carbon steel and canela carbide inserts. The cutting tools undergone machining tests by CNC turning operation and their performance were evaluated by the surface roughness value and the observation on the surface roughness profile. The machining tests were held at varied cutting speed of 35 m/min to 53 m/min, feed rate of 0.15 mm/rev and 0.50 mm/rev and constant depth of cut of 1mm. From the analysis, it was found that surface roughness increased as the cutting speed increased at the lower feed rate of 0.15 mm/rev whereas at the higher feed rate of 0.5 mm/rev, surface roughness decreased as the cutting speed increased. Varian of surface roughness suspected due to nose radius conditions, whether from tool wear or formation of built-up edge. This study helps to understand the effect of spindle speed and feed rate on surface integrity when machining AISI 1045 carbon steel using carbide cutting tools under wet and cutting condition.

DEDICATION

To my beloved parents and siblings

ACKNOWLEGDEMENT

First and foremost, I would like to express my greatest gratitude to Almighty God for giving me strength and courage to finally complete my bachelor degree project with the best I could. Indeed, without His Help and Well, nothing will be accomplished.

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CHAPTER 1
INTRODUCTION

This section explains about background, objective and scope of the study. Background discusses about the type of material used, CNC lathe machine and performances of machining that need to analyse. While the objective mentions about the mission that needed to be achieved for this project and scope covers everything what is supposed to do in this project.

1.1 Background of Study

Machining is a process to produce the component parts by removing the material into required shaped. This process applied in major industrial practice such as automotive, aerospace, medical, oil and gas and nuclear. There are three major factors that contributed to the efficiency of machining which is cutting tools, workpiece material and cutting parameters. In the manufacturing field today, machining of material is getting leading as there are various advancements of new alloys and engineered material which ultimately causes these materials to have high strength, toughness, and other material properties. In manufacturing operations, it is imperative to view the machining operation as a system, comprises the workpiece, machine tools, cutting tool and also production personnel. Machining cannot be carried out efficiently or economically and also meet stringent part specifications without a detailed knowledge of the interactions between these four components (Kalpakjian & Schmid, 2013).

One of the materials that commonly used in the industry is steel. The important of steel widely used nowadays around the world in industry sector, including aerospace, automotive, aircraft and chemical. In a group of steels, there are two types of steels which are plain carbon steel and alloy steels. In this study, materials used is AISI 1045 which classified into plain carbon steels. Plain carbon steel is the one in which the only alloying element is carbon. Carbon being a powerful alloying agent can present a kind of strength and hardness by varying its composition in the steel. It is in this regard that carbon steels are branched into three main groups that are low-carbon steel, medium-carbon steel and high-carbon steel (Larry Horath, 2011). AISI 1045 contain carbon composition between 0.43% - 0.50%, which its fall under group medium-carbon steel. It has good mechanical properties such as good machinability, high strength, and high hardness. In recent years, there has been an increasing curiosity in research of machinability AISI 1045 that concentrate to reduce manufacturing cost and increase productivity (Kishawy et al, 2009).

In sector industry, turning is the most common process use and is an engineering machining process which is used to produce rotational parts by cutting away unwanted material. Turning can be done manually, in a traditional form called as lathe, which frequently requires continuous supervision by the operator. Nowadays, the industrial sector is increasing with the new technologies which are use automated system called as computer numerical control, better known as CNC. By using CNC machining, the process is more precise than manual machining, and can be repeated in exactly the same manner over and over again. In this process, it is vital to select input (cutting) parameters with great precision for achieving high cutting performance (A. Qasim et al, 2015).

One of the important criteria to evaluate the performances of machining is the surface integrity. Surface integrity is a critical consideration in manufacturing operations because it influences properties like fatigue strength, resistance to corrosion, and service life. Surface topography and surface metallurgy are under surface integrity. Surface topography is about the roughness, about the texture at the outer of the surface of the workpiece. Surface metallurgy is about the nature of the altered layers below the surface with respect to the base or matrix material. To get a better quality control,

the surface roughness is important things that should be consider. To produce a better quality product in industry, the value of surface roughness must be lower (Gupta & Kumar, 2015). For that reason, a study of surface roughness is important in order to relate the condition of the machined surface with respected parameter.

There are two conditions in machining which is dry and wet. Dry machining is a process where cutting fluid will not be used when doing machining process. Advantage dry machining is to reduce the use of fluid that probably can reduce cost as well as to reduce impact hazard to the environment. Dry cutting normally employs for finishing process to gray cast iron or powder base material. On the other hand, wet cutting is process where fluid is applied in machining environment to provide cooling and lubrication. This process enables to produces longer tool life and fine surface finish. However, the use of fluid in machining may produce some disadvantages such as hazard to the environment, effect to machinist skin and increase cost machining. Therefore, as the both dry and wet cutting provide a certain advantage and disadvantage the comparison study for this two processes must be conducted in order to determine which process is suitable in machining particular material.

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 the tool. The evaluation of this research will be examined using Portable Surface Roughness Tester, Stereo Microscope (SM) and Scanning Electron Microscope (SEM).

1.2 Problem Statement

Surface integrity is one of the main criteria to evaluate the quality and performance of a product after undergo machining process. In order to achieve the best performance of AISI 1045, the cutting parameter must be applied correctly during the machining process. Parameters that give a huge influence on the surface quality is cutting speed and feed rate while the depth of cut is not really give huge effect to the surface. Machining AISI 1045 normally applied in dry condition where the processes normally applied for finishing and clean environment. Despite it give good finishing but in dry condition it sometimes produces quick tool wear due to high friction at the cutting interface. There are other techniques such as wet cutting that also applicable during cutting AISI 1045. This technique reportedly produced longer tool life (Kalpakjian, 2011) due to low friction and cooler environment. However, using coolant will provide hazard to environment, the availability at dry and wet cutting for AISI 1045 raised the question of which techniques is better to machine this material. There are cases where machining AISI 1045 may produce best surface finish in dry condition when the cutting parameters applied correctly. There are also cases machining AISI 1045 gave worst surface finish in wet condition when it applied in improper cutting parameters (List et al. 2009). Therefore, it is necessary to study the comparison for both cases, wet and dry conditions in order to evaluate the best surface finish and tool wear when machining AISI 1045. This study will investigate which cutting conditions give the best surface finish on machining AISI 1045.

1.3 Objectives

The objectives of this study are:

    i.   To study the effect of cutting speed on surface roughness during machining AISI 1045 at dry and wet conditions.

   ii.   To observe surface profile based on machining AISI 1045 at dry and wet conditions.

  iii.   To compare the surface integrity of AISI 1045 at dry and wet conditions.

1.4 Scope

This study is to investigate the feasibility of cutting condition to machine AISI 1045. Dry and wet cutting condition of machining will be compared based on the surface integrity. In this project, the selected process is turning which will be performed by using a CNC turning machine; the varying parameter is cutting speed and feed rate while the depth of cut is kept constant. The performance measures to be evaluated are the surface roughness will be analysed using a surface roughness tester. Surface profile will be analysed using microscope. The effect of cutting speeds on surface integrity of these materials will be studied and evaluated in details. This study consists of five chapters which is covers introduction, literature review and methodology, results and discussions and conclusion.

CHAPTER 2
LITERATURE REVIEW

The literature review part consists of the summarizing of the project in order to get the whole data about workpiece material, cutting tools and lathe machine information, this will give an idea to run the project. This chapter presents related study done by previous research and will be working as a reference, to give information and guide base on journal, book and other source on the internet that could contribute to this project.

2.1 Steel

Steel is generally a compound of iron and carbon, with the carbon content varying up to 1.5%. The hardenability of the steel is depends on the carbon content, the higher the carbon, the higher the strength and wear resistance. Various alloying elements are added to steel in addition to carbon in order to impart the properties of hardenability, strength, hardness, toughness, wear-resistance, workability, weldability and machinability. Carbon and alloy steels are among the most commonly used metals and have a wide variety of compositions, processing options, and applications. These steels are available in various basic product shapes such as plate, sheet, strip bar, wire, tube, castings and forgings (Kalpakjian & Schmid, 2013).

2.1.1 Carbon Steel or Plain Carbon Steel

Plain carbon steel is a mixture of iron and carbon with low quantities of manganese, silicon, sulfur and phosphorous. The primary aim of these alloying elements is not to alter the mechanical properties of the steel. The carbon content may vary in the range from a trace to 1.7%, although rarely over 1.3%. Plain carbon steels containing more than 1.3% carbon are seldom produced or used (Larry Horath, 2011).

Plain carbon steels are divided into three groups, according to carbon content, as follows:

➢ Low carbon steel
  Called as mild steel, it has carbon content less than 0.30%. It possesses good formability and weldability but lacks hardness. The structures of such steels are usually ferrite and pearlite. It is used in making bolts, nuts, sheets, plates, tubes and machine components that do not require high strength.

➢ Medium carbon steel
  The carbon composition is in the range 0.30 % to 0.60%. It has higher strength than low-carbon steels. The increasing carbon content makes them harder. These steels are extremely popular, because the properties of such steels are greatly improved by heat treating and therefore they are best adapted for machine parts such as gears, axles, connecting rods, crank shafts, railroad equipment, and parts for metal working machinery.

➢ High carbon steel
  Carbon composition content more than 0.60%. The highest practical limit is 1.3%. Toughness and formability of such steels are quite low, but hardness and wear resistance is high. Therefore, they are generally used for parts such as cutting tools, cable, springs and cutlery.

2.2 AISI 1045-Medium Carbon Steel

AISI 1045 has classified under types of medium carbon steel according to the carbon composition. AISI 1045 is characterized by good weldability, good machinability, and high strength and impact properties in either the normalized or hot rolled condition. AISI 1045 is one of the material widely used in the industry nowadays because of its capability that easily can be made in mold, template, mortise pin, column. This kind of steel has good mechanical property, is broadly used in structural parts which may support stress alternation, especially made into some connecting rods, bolts, wheel gear and shaft parts (Nunura et al., 2015). The machinability of AISI 1045 varies with its microstructure and hardness due to the carbon composition inside the material itself.

2.2.1 Chemical Composition

The chemical composition of the AISI 1045 is shown in the Table 2.1:

Table 2.1: Chemical Composition of AISI 1045

(Source:http://www.azom.com/article.aspx?ArticleID=6130>17/09/15)

Element	Content
Carbon, C	0.420 - 0.50 %
Iron, Fe	98.51 - 98.98 %
Manganese, Mn	0.60 - 0.90 %
Phosphorous, P	≤ 0.040 %
Sulfur, S	≤ 0.050 %

2.2.2 Mechanical Properties

The mechanical properties of the AISI 1045 is shown in the Table 2.2:

Table 2.2: Mechanical Properties of AISI 1045

(Source:http://www.azom.com/article.aspx?ArticleID=6130>17/09/15)

Mechanical Properties	Metric	Imperial
Hardness, Brinell	163	163
Hardness, Knoop (Converted from Brinell hardness)	184	184
Hardness, Rockwell B (Converted from Brinell hardness)	84	84
Hardness, Vickers (Converted from Brinell hardness)	170	170
Tensile Strength, Ultimate	565 MPa	81900 psi
Tensile Strength, Yield	310 MPa	45000 psi
Elongation at Break (in 50 mm)	16.0 %	16.0 %
Reduction of Area	40.0 %	40.0 %
Modulus of Elasticity (Typical for steel)	200 GPa	29000 ksi
Bulk Modulus (Typical for steel)	140 GPa	20300 ksi
Poissons Ratio (Typical for Steel)	0.290	0.290

2.3 Machining

Machining processes is defined by metal parts are shaped by removal of unwanted materials (Cheng, 2012). 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.

2.3.1 Machining Element

There are several main elements that are required for a machining process completed shown in Table 2.3 (Kalpakjian & Schmid, 2013). Figure 2.1 shows the mechanism of cutting during machining process.

Table 2.3: Primary element of machining (Source: 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.
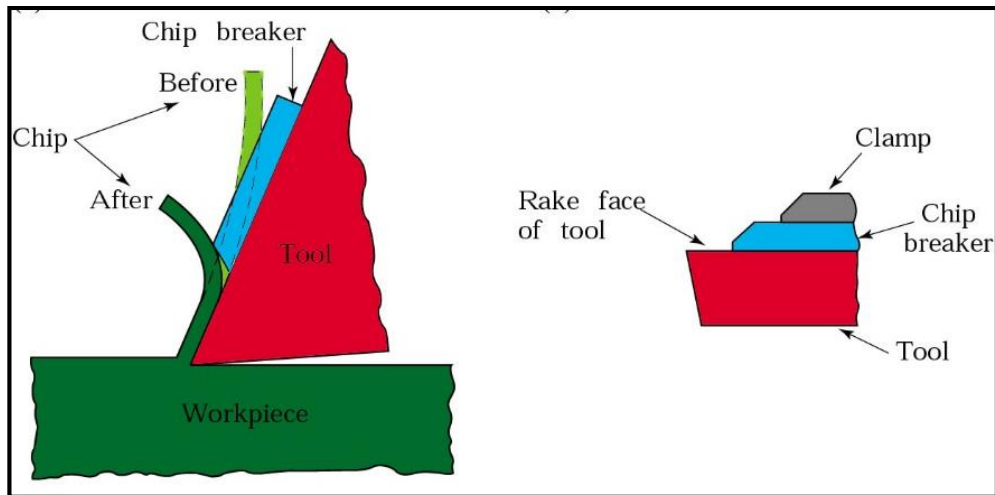
Figure 2.1: Machining by cutting (Kalpakjian & Schmid, 2013)

2.4 CNC Lathe Machine

CNC Lathe Machine is one of the machine tool that has been used in manufacturing production. About one third of the machine tools and operation in engineering plants is lathe machine. Primarily lathe machine was designed to perform turning, facing and boring operations on a cylindrical workpiece. Nonetheless, other operations such as drilling, tapping, tapering, reaming, knurling and threading are possible on the lathe when various cutting tools and attachments are used (Helmi and El-Hofy, 2011). These machines are highly versatile and capable of a number of machining process that produces a wide variety of shapes. Figure 2.2 shows the typical CNC lathe machine in the industry.

Figure 2.2: CNC lathe machine in the industry.
(Source: Helman CNC, 2011)

2.4.1 CNC Lathe Components

Lathes are equipped with a variety of components and accessories such as bed, carriage, headstock, and tailstock as shown in Figure 2.3.

Figure 2.3: Component of lathe machine
(Source: < http://americanmachinetools.com/how_to_use_a_lathe.htm> 12/11/15)

a) Bed

Bed is the base of lathe machine because it supports all major components in the lathe. The bed is built rigid and made from grey or nodular cast iron. The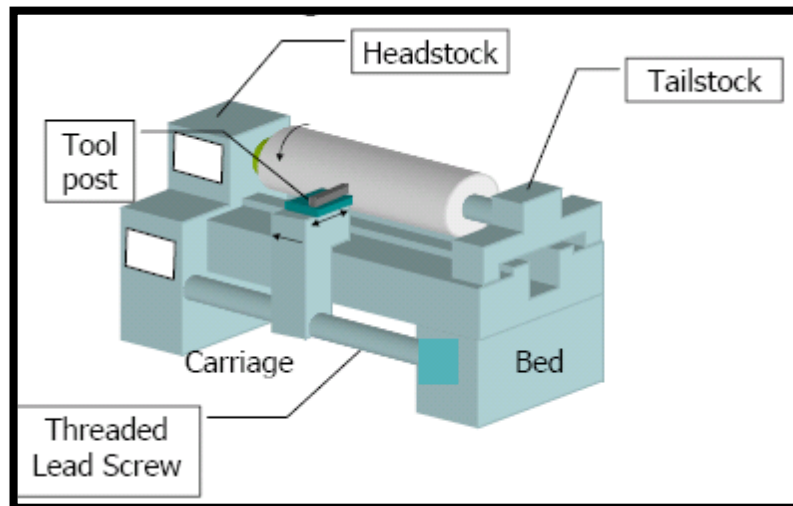 main features of beds construction are the ways in which formed at the top portion besides run the full length of the bed.

b) Headstock

The headstock is permanent to the bed and it equipped with motors, pulley, and belts. It rotates the workpiece by using a chuck. It driven by an electric motor connected either to a belt or pulley system or to a geared system. The speed can be set manually through controlled selector or by electrical control. For long bars or tubing workpiece, holding device such as chuck and collets is used with headstock for various turning operations.

c) Tailstock

The tailstock is placed at the opposite end of the lathe from the headstock. Tailstock can be clamped in any position and can slide along the ways and support the other end of the workpiece.

d) Carriage

The carriage consists of apron, saddle, compound rest, cross slide and tool post that slides along the ways. Carriage is used to move and carry the cutting tool. The cutting tool is attached on the tool post. The cross slide moves radially in and out controlling the radial position of the cutting tool. The apron is equipped with mechanism for both manual and mechanized movement of the carriage and the cross slide by means of the lead screw.

e) Lead Screw and Feed Rod

The feed rod is driven by a set through of the headstock. Through lathe operation the rod is rotate and provides movement to the carriage by means of gears, a friction clutch and a key way along the length of the road.

2.4.2 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 intersects with the turning axis. Lastly is transverse turning, this type of turning occurring when the direction of the tool feed motion is perpendicular to the turning axis. This type of turning can be divided into radial and facing turning.

Turning is used to reduce the diameter of the work piece usually to a specified dimension, and to produce a smooth finish on the metal. Often the work piece will be turned so that adjacent sections have different diameters. Turning is the machining operation that produces cylindrical parts (Khandey, 2009).

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2.4.3 Cutting Process

Lathe machine is capable to operate several machining operations. Figure 2.4 shows a various operation that is performed by lathe machine. Lathe machine is known widely as versatile machine that capable to produce various cutting shapes and process.

Lathe machine is capable to operate several machining operations such as

- Turning – a process that produces straight conical, curved, or grooved workpiece
- Facing – Cutting on perpendicular to its axis and produce a flat surface on the part
- Cutting with form tool – form tool is used to produce various axis symmetric shapes for functional or aesthetic purposes.
- Boring – To enlarge an existing hole that has been produced by previous process and to produce internal grooves
- Drilling – To produce new hole
- Cutting off – To cut the workpiece
- Threading – To produce external and internal threads
- Knurling – To produce diamond shape on the surface to make it knob or handle
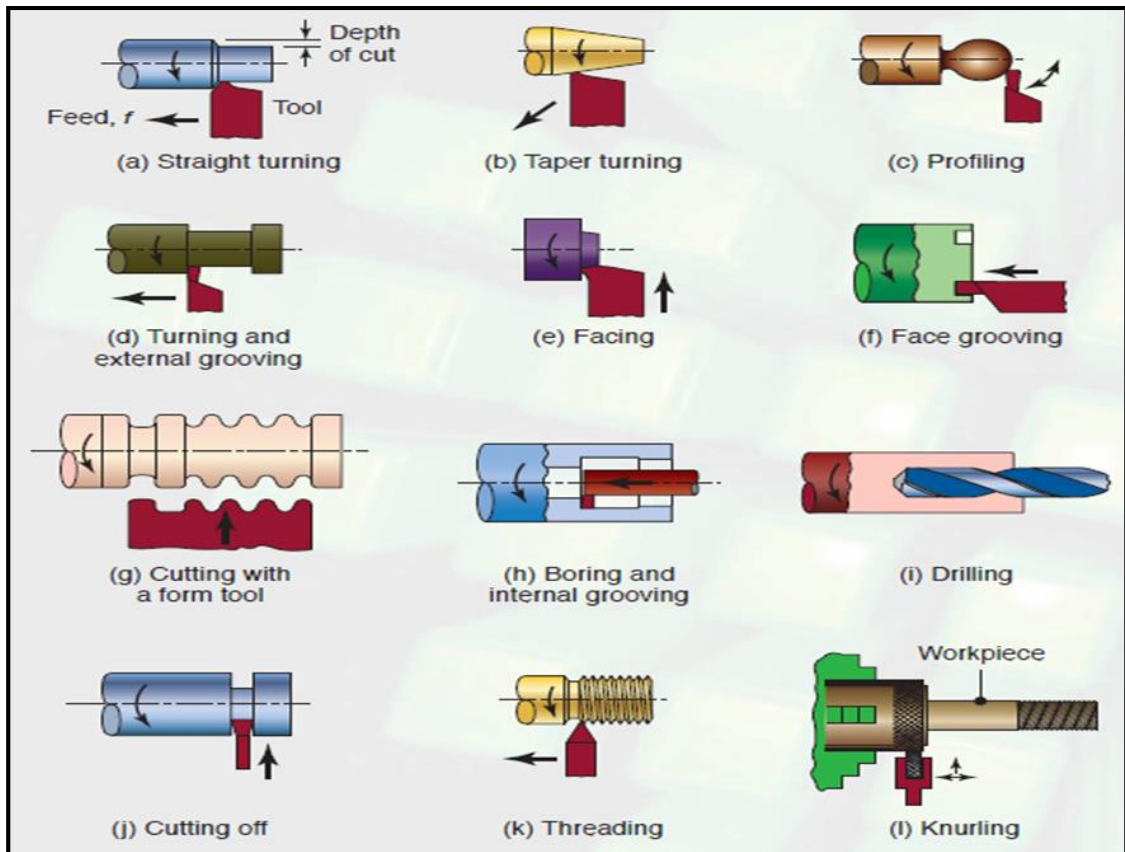
Figure 2.4: Various cutting operations that can be made by lathe machine

(Kalpakjian & Schmid, 2013)

2.5 Turning Process Parameter

According to Arthur et al (2002), process parameter has a direct influence on machining process and it important to control, these parameters to get optimized productivity. Turning process parameters such as tool geometry, cutting speed, depth of cut is important to control in order to get better finishing product with low cost and high productivity. The selection to efficient machining parameters such as machining speed, feed rate and depth of cut has a direct impact in the metal cutting processes (Prasad, 2013).

2.5.1 Tool Geometry

The various angles in a single-point cutting tool plays an important function im machining operation (Kalpakjian & Schmid, 2013). 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 – It is significant in holding both the way of chip flow and the strength of the tool tip. Positive rake angles can improve the cutting operation by reducing forces and temperatures. Nevertheless, 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 are more important than the back rake angle and it generally controls the direction of chip flow and. Common angle for machining carbide inserts are in the range from -5 ° to 5 °.

c) Cutting edge angle – Cutting force, chip formation and tool strength usually 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 excessive.

e) Nose radius – Surface finish and tool-tip strength will affect by nose radius. The smaller the sharp tool, the rougher the surface finish of the workpiece and the lower the strength of the tool. Nevertheless, large nose radii can lead to tool chatter.

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Figure 2.5 shown are recommended tool geometry for turning process for various workpiece materials

General Recommendations for Tool Angles in Turning

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 2.5: General Recommendations for Tool Angles in Turning

(Kalpakjian & Schmid, 2013)

2.5.2 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. Table 2.4 below show the formula for turning parameters. To calculate the material removal rate (MRR) is using the formula below:

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

Where,

$$D_{avg} = \frac{D_0 + D_f}{2} \qquad \text{Eq 2}$$

It also can be,

$$MRR = df V \qquad \text{Eq3}$$

Where,

$$t = \frac{1}{fN} \qquad \text{Eq4}$$

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Table 2.4: 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

2.5.3 Cutting Speed

Cutting speed can be defined by the rate at which a point on the circumference of the workpiece move passed the cutting tool. Cutting speed is expressed in meters per minute (m/min). Magd et al, (2002) mentions to get better production rate and cutting tool life, cutting speed must be determined by cutting tools and metal manufacture.

$$V = \pi DN \hspace{4cm} Eq\ 5$$

Where,

V = Cutting speed (m/min)

D = Diameter of the workpiece (m)

N = rotational speed of workpiece (rpm)

2.5.4 Spindle Speed

The diameter of the work and the cutting speed of the material must be known in order to calculate the number of revolutions per minute. The formula for calculating the spindle speed is:

$$r/min = \frac{V \times 320}{D}$$

Eq6

Where,

V = cutting speed (m/min)

D = diameter of workpiece (mm)

2.5.5 Feed Rate

The feed rate is defined as the cutting tool to advance alongside the length of the work for every revolution of the spindle. For example, if the lathe is set for a 0.20 mm feed, the cutting tool will travel along the length of work which is 0.20 mm for every complete turn of the workpiece. There only two cuts should be taken to bring diameter to size which is roughing cut and a finishing cut.

2.5.6 Depth of Cut

Depth of cut (*d*) is the distance of cutting tool penetrates into the workpiece. The depth of cut is essentially self-explanatory. According to Molian (2006), 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. In turning depth of cut can be calculated as:

$$d = \frac{D_0 + D_f}{2}$$

Eq 7

Where,

Do = Original workpiece diameter (mm)

Df = Final workpiece diameter (mm)

2.6 Chip Formation

Chip formation depends on the workpiece material and the machining condition. Chip formations that are formed will significantly affect the surface roughness and workpiece dimension. During cutting process, there are three types of chips formation can produce. The heat generate during a cutting operation is the summation of plastic deformation involve in chip formation and the friction between tool and work piece and between tool and chip (Khidhir et al, 2009). Tool chips have been classified into three types as shown in Figure 2.6 (Kalpakjian and Schmid, 2009).
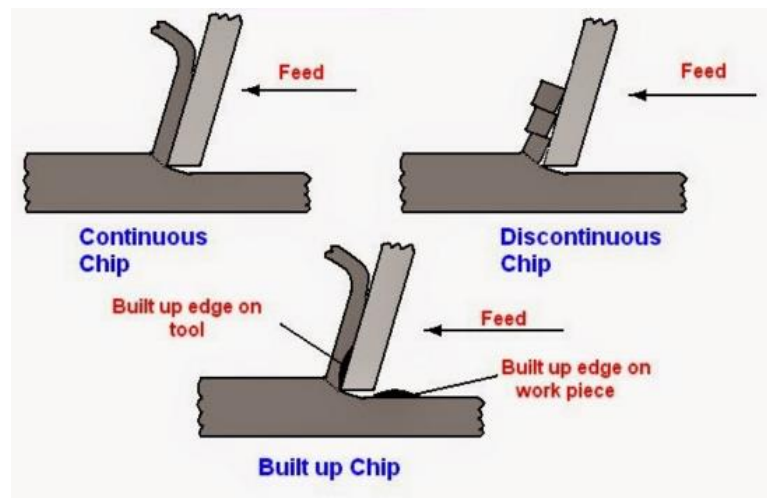

Figure 0.6: Type of chips formation (Kalpakjian and Schmid, 2009)

(a) Continuous chip

Continuous chips are formed with ductile materials at high cutting speeds and high rake angles. Continuous chips tend to become tangled around the tool holder, the fixturing, and the workpiece, as well as chip-disposal system, and the operation has to be stopped to clear away the chips. This problem can be alleviated with chip breakers and by changing machining parameters, such as cutting speed, feed, and cutting fluids.

(b) Discontinuous chip

Discontinuous chips consist of segments that may be firmly or loosely attached to each other. It normally obtained in cutting ductile materials and provides good surface finish.

(c) Build-up edge chip (BUE)

A built-up edge (BUE), consisting of layers of material from the workpiece that are gradually deposited on the tool, may form at the tip of the tool during cutting. As it becomes larger, the BUE becomes unstable and eventually breaks up. However, as the cutting speed is increased, the size of the BUE decreases and the surface finish is improved.

2.7 Selection Cutting Tools

Cutting tool plays an important factor in machining technology. The selection of cutting tool before this are not being indicate cause of lack knowledge about impact to the machining process from the selection unsuitable cutting tool. Nowadays, tooling technologies are treated extremely seriously because of the optimum production output and consistency of machined product activities are being realised (Kalpakjian & Schmid, 2013).

2.7.1 Cutting Tools Materials

There are many types of cutting material in order to perform the machining process according to the application. Wrong selection cutting tool material will give inappropriate result of machining process, this can produce a problem like shortened tool life, edge chipping and insert breakage are likely if feed rates are too high, whereas when feeds are too low, chip control becomes a problem. The fews type of cutting tools material is:

a) High Carbon Steel

Carbon steel were used for all cutting tools, where their carbon content ranging from 0.80% to 1.2%. These steels have good with heat treatment and hardening properties and with proper heat treatment, attain as great hardness as any high-speed alloys (Kalpakjian and Schmid, 2013).

b) High Speed Steel

Kalpakjian and Schmid (2013) state that high speed steel (HSS) the composition of this material normally consisted of 18% tungsten and 5.5% chromium as the dominant alloying elements. This material has ability to resist softening at high temperatures is known as hot hardness and with adequate quality. Because of their hot hardness ability, this material was used as a cutting tool for machining soft material such an aluminum or Teflon.

c) Carbide

Carbide are introduced because of their high hardness over a wide range temperature, have high elastic modulus, high thermal conductivity, and low thermal expansion. Carbide are among the most important, versatile, and cost-effective tool and die materials for a wide range of applications. There are two types of carbide that used in machining which is tungsten carbide and titanium carbide.

d) Diamond

Diamonds used as single-point tools because of their high hardness and brittleness for light cuts and high speed cuts. They are used either for hard materials difficult to cut with other tool materials or for the light cuts on softer materials where accuracy and surface finished are important.

2.8 Cutting Fluids

Main function of cutting fluid is to remove the formation of chips at cutting zone. Hence, the chips will not interfere with further processing. The cutting fluid act as lubricant to avoid chip tool interactions within the flutes. The cutting fluid is effective in cooling and lubricating workpiece (Liu et al., 2009). Its function as reducing friction among the cutting tools, chips and workpiece. According to Sharma (2015) cutting fluid perform the primary function of heat dissipation and lubrication during metal cutting operations. Cutting fluid is important in assist the machining process. Besides that, it is also said to be accounting to major expenditure in any metal cutting industry, in fact more than cost of cutting tool.

2.8.1 Purpose Cutting Fluids

Cutting fluid was used to cool and lubricate both the workpiece and cutting tools edge. In addition, it can improve the machined surface quality and an increase in tool life (Dhar et al, 2006). The main benefits of using cutting fluids are:

(a) Lubrication

It can help reduce of formation built-up edge in cutting insert. It also can reduce spindle power consumption and lubrication of chip passage over the insert. Coefficient of friction at the chip and tool interface also will be reduce.

(b) Surface Quality

Both heat removal and frictional improvement aims in obtaining improved machined component surface texture and integrity.

(c) Tool Life

Heat removal and friction can be reduced during machining operation hence will increases the tool life.

2.9   Surface Integrity

Surface integrity is a term that represents the conditions of characteristics of the workpiece material surface after machining process. It generally can be divided into two aspects which are the external topography of surfaces (surface finish) and the mechanical properties, microstructure and residual stresses beneath the subsurface layers (J. Paulo Davim, 2010). Surface integrity are very important in relation to performance characteristics such as fracture strength, fatigue strength, corrosion rate and tri biological behaviour such as friction, wear and lubrication, and dimensional accuracy According to Davim et al (2010), the term surface integrity is used to describe the attributes of a machined surface and its relationship to functional performance.

2.9.1   Surface Roughness

Surface roughness is one of the main features in metal cutting that being identified in machining processes. There are many different types of machines being used in metal cutting. Surface roughness is a commonly problem in machined surfaces and also can be called as the finer irregularities of surface texture (Hussein, 2014). The product quality depends greatly on the surface roughness. When the surface roughness decreases, the product quality will increase. Kumar et al. (2012) stated that surface roughness plays an important role in affecting wear, lubrication of contacting bodies and also the friction. It can be said that surface roughness greatly influences the friction under certain running conditions.

Surface roughness has greatly influences to the manufacturing cost. It consists of the feed marks generated by the machining process. In evaluating the productivity of machine tool and machine parts, the quality of surface is significantly the important factor. Not only in term of tolerances, but a good surface product also reduces the assembly time and avoids the need of secondary operation and leads to cost reduction (Rana and Panchal, 2014).

The arithmetic mean value (Ra) is based on the schematic illustration of a rough surface as shown in Figure 2.7. It is defined as

$$Ra = \frac{a + b + c + d + \dots}{n}$$

where all ordinates a, b, c, …, are absolute values and n is the number of readings.

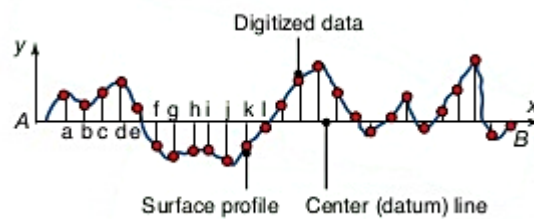Figure 2.7 Coordinates used for surface roughness measurement.

2.9.2 Surface Profile

Surface profile is a term to represent the surface characteristics of the surface material after done machining process. For normal machined surface, the formation of feed rate of the cutting tool nose radius may emerge. However, in some cases, surface damage such a micro crack, material side surface or porosity may also appear in surface profile due to some phenomenon during machining. The surface profile can be measured using optical measuring instruments such as microscope, particularly Scanning Electron Microscope (SEM).

CHAPTER 3
METHODOLOGY

This chapter presents the methodology used in this study in order to obtain the analysis of surface integrity when machining AISI 1045 with carbide under dry and wet condition. The machining process has been conducted under varying parameters of cutting speed and feed rate with constant depth of cut (DOC). In order to do this project, the machining of AISI 1045 has been carried out using a CNC turning machine, where the entire experimental test has been performed at the laboratories of Faculty of Technology Engineering, Universiti Teknikal Malaysia Melaka (UTeM).All data were shared together with the studies from Shahida and Zara. Through the experiment, surface roughness, and surface profile has been analysed as a main criterion to evaluate the efficiency of machining. The surface roughness has been tested using surface roughness tester while the machined surfaces have examined under an optical microscope and Scanning Electron Microscope (SEM). This section describes the machines and equipment needed, experimental procedure, and analysis of the material in order to achieve the objectives of this research. The methodology flowchart is illustrated in Figure 3.1.
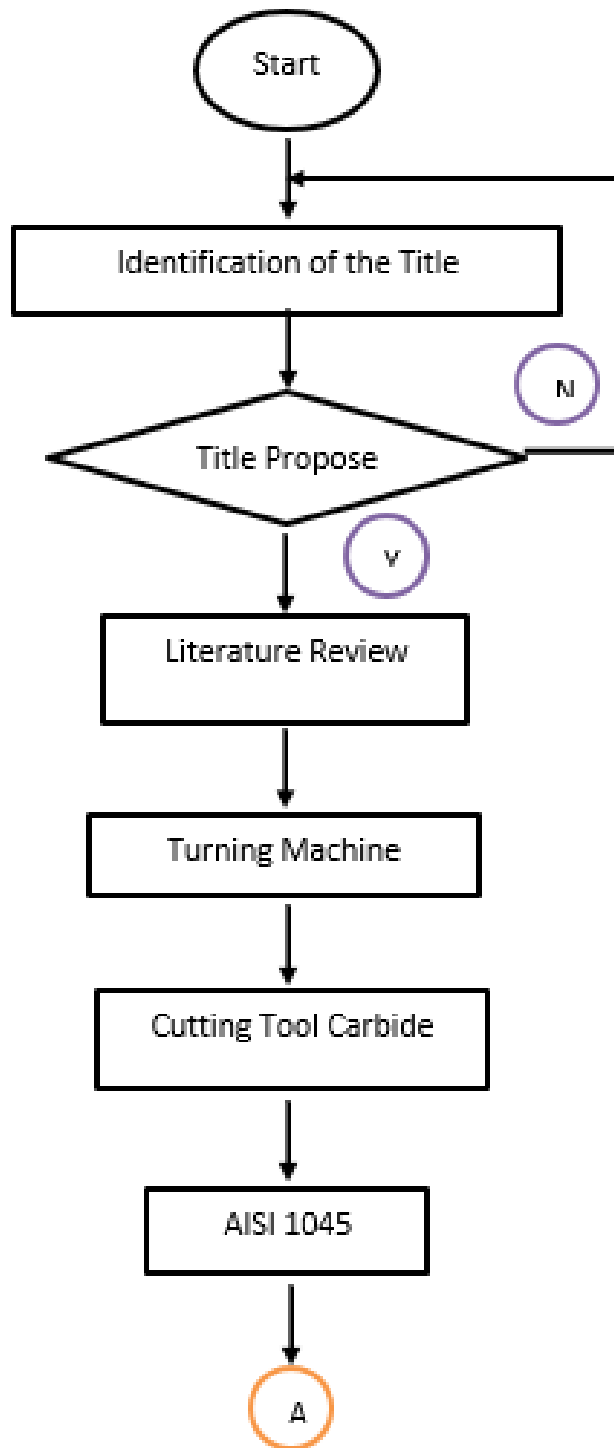
3.1 Flow Chart
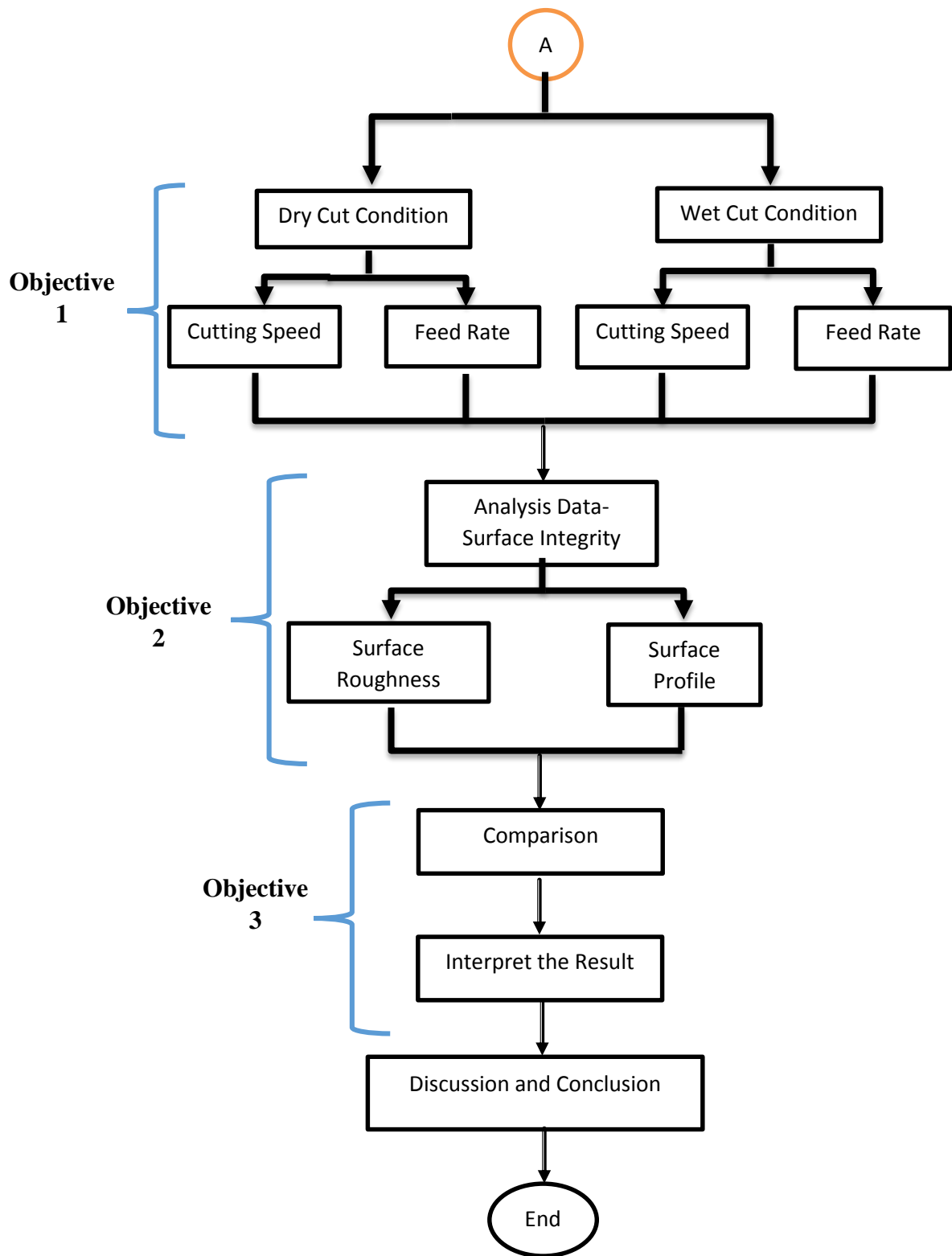

Figure 3.1: The flowchart of FYP.

Figure 3.1: The flowchart of FYP (cont'd)

3.2 Material Selection

Material selection for workpiece and cutting tool is the most important for this experiment because every material has different properties that can be affected from the parameter that was selected. The suitable selection of material is the most significant aspect to take into consideration in processes related to the experiment. From the discussion with the supervisor and literature review, the workpiece that was used in this machining are AISI 1045 which is plain carbon steel and cutting tool are carbide insert with code number is TNMG160404- DM Material that will be used is AISI 1045 a medium carbon steel designed to be able to function in areas requiring greater strength and hardness. The workpiece material is AISI 1045 as shown in Figure 3.2 and Table 3.1 show its properties. This material will be machined in wet and dry condition. The type of coolant will be used for wet cutting condition is cutting oil.

3.2.1 AISI 1045 Medium Carbon Steel

The workpiece material is AISI 1045 as shown in Figure 3.2 and Table 3.1 shows its properties.

Figure 3.2: The AISI 1045 Steel Bar

Table 3.1: Properties of AISI 1045 Steel

Properties	Metric
Density (kg/m^3)	7870
Elastic Modulus (GPa)	206
Tensile Strength (MPa)	585
Hardness (HB500)	163
Shear Modulus (GPa)	80

3.3 Cutting Tool

The cutting tool that will used in this machining is carbide insert with code number is TNMG160404- DM that shown in Figure 3.3 and Table 3.2 shows information about carbide.

Figure 3.3: Carbide Insert

Table 3.2: The information about carbide inserts (Source: Carbide Depot, 2015)

Name	Description
ISO Code	TNMG160404-DM
Material	Tungsten Carbide
Angle	60^0
Shape	Triangle

Application	Turning
Chip Breaker	DM
L	16.5 mm
I.C.	9.525 mm
S	4.76 mm
d	3.81 mm
r	0.4 mm

3.4   Process Parameter

During the experiment, various cutting speeds and feed rate were tested when machining AISI 1045, meanwhile other parameters are keep constant. In this experiment, four cutting speeds and two feed rate have been selected in order to investigate the surface characteristics based on cutting speed variable. Table 3.3 shows all cutting parameters that will be applied in the experiment include cutting speeds and feed rates.

Table 3.3: Experiment Parameters

Cutting Speed (m/min)	Feed rate (mm/rev)	Depth of Cut (mm)	Cutting Condition	
35	0.15	1.0	Dry	Wet
41			Dry	Wet
47			Dry	Wet
53			Dry	Wet
35	0.5		Dry	Wet
41			Dry	Wet
47			Dry	Wet
53			Dry	Wet

3.5 Machining and Equipment

For the machine and equipment used in this experiment are:

    (a) CNC Lathe Machine

    (b) EDM Wire Cut

    (c) Surface Roughness Tester

    (d) Stereo Microscopes

    (e) Scanning Electron Microscopes.

3.5.1 CNC Lathe Machine

This experiment was conducted by CNC lathe machine model DMG MORI SEIKI, CTX 310 ecoline. The CNC lathe machine that was used in this experiment was shown in Figure 3.4 below and Table 3.4 shows the CNC lathe machine specification.

Figure 3.4: CNC Lathe Machine DMG Mori Seiki CTX 310 *ecoline*

Table 3.4: CNC Lathe Machine Specification

Specification	
Machine Serial Number	310
Model Number	CTX
Brand Name	SLIM*line* panel 15 ´´
Machine Made	DMG Mori
Max Turning Diameter	⌀200 mm
Drive Power	16.5 kW
Machine Weight	3800 kg
Machine Speed	5000 RPM
Application	Turning, facing, putting, knurling, screw thread run out, boring, screw thread undercut, radius or curvature and drilling.

3.5.2   Steps in Turning Operation

a)   Marking process on the workpiece

First of all, the AISI 1045 was undergone centre drilling process at the edge of both sides. The centre drilling process is done by using conventional turning machine. The purpose of centre drilling process is to make sure correct alignment of the cylindrical AISI 1045 in the machine being placed centrally during CNC machining process. The process of centre drilling can be shown as in Figure 3.5.

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Figure 0.5: Centre drilling process

b)   Clamp the workpiece

The workpiece then clamped using 3 jaw chuck. During material setting, balance between length and support from the tailstock is very important to avoid vibration during machining. Both dry and wet cutting was set according to the similar cutting length, for all cutting parameters that will be investigated. Figure 3.6 shows the position of AISI 1045 carbon steel setting on CNC turning machine

Figure 3.6: Clamped workpiece

(c)   Turning operation

After that, a simple CNC program was generated to run the CNC turning machine at various machining parameters. Dry cutting process was carried out as no lubricant and cutting fluid present during wet machining condition. Every 5 mm cutting length was considered as one pass. The CNC turning machine that was being used for this project was DMG Mori Seiki CTX 310 *ecoline*. Figure 3.7 shows the CNC turning process.

Figure 3.7: CNC turning process using DMG Mori Seiki CTX 310 *ecoline* turning machine.

3.6 Sample Preparation - EDM Wire Cut

The workpiece has been cut into eight specimens with each dimensional 1mm $\times$ 1mm $\times$ 1mm by using Wire Cut Electrical Discharge Machining (EDM) shows in Figure 3.8. The purpose of this machining process is to obtain the desired size of specimens in order to simplify the further tasks for doing the analysis.

Figure 3.8: Wire Cut Electrical Discharge Machining (EDM)

3.7 Data Analysis

The equipment used in analysis of the surface integrity are:

(a) Surface Roughness Tester

(b) Stereo Microscopes

(c) Scanning Electron Microscopes.

3.7.1 Surface Roughness Tester

Surface roughness test is a profiling technique that will begin with the stylus measurement. It is a contact type roughness instrument as it will directly contact to the surface of the AISI 1045 carbon steel. In this study, the surface roughness test instrument that has been used was Mitutoyo Surftest SJ-410. Figure 3.9 shows the surface roughness tester of Mitutoyo Surftest SJ-401 while Table 3.5 shows its general information.
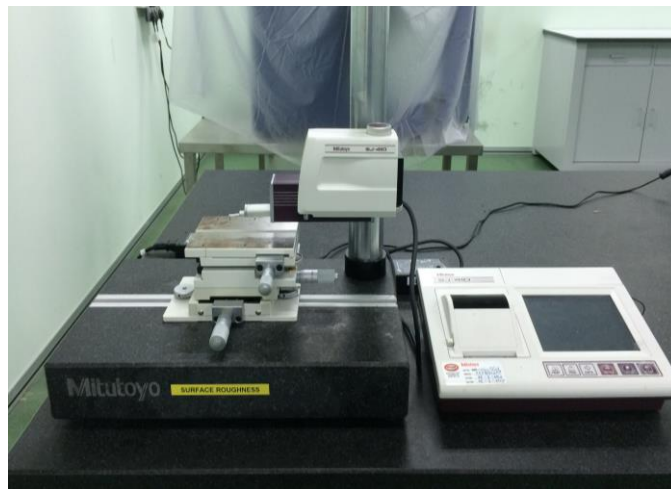
Figure 0.9: Surface roughness tester of Mitutoyo Surftest SJ-401.

Table 0.5: General specifications of surface roughness tester

No	General Information	
1	Serial number	178-956-3 D
2	Measuring method	Skid-free/ with skid (switchable)
3	Measuring range: Z-Axis X-Axis	 800 mm, 80 mm, 8 mm 25 mm
4	User-defined	Display/roughness parameter selectable
5	Location	Metrology Lab (FTK, UTeM)

The workpiece was placed on the flat surface and must be secured from any movement during testing. The contacting stylus of the surface roughness test instrument is placed directly over the centre of the test sample. Then, the tip of the stylus will directly touch the surface of the sample. The stylus traced across each marked area for each experiment about 3 mm. The uses of stylus at the contact surface of workpiece is shows in Figure 3.10.

Figure 0.10: The uses of stylus at the contact surface of workpiece

3.7.2 Stereo Microscope

Stereo microscope are used to observed the surface profile of AISI 1045 after machining under wet and dry condition with different cutting speed under low magnification (1.5 x magnificent).Figure 3.11 shows stereo microscopes and Table 3.6 shows general information of stereo microscopes.

Figure 3.11: Meiji Stereo Microscopes type EMZ

Table 3.6: General Information for Stereo Microscopes

Machine Specification	
Manufacture	Meiji techno
Model No	EMZ-13TR
Zoom Ratio / Zoom Range	7:1 /1.0x - 7x

3.7.3   Scanning Electron Microscope

For surface profile characteristic electron scanning microscopes was used. This instrument able to capture images on cutting tool that cannot see with naked eyes. It also has a magnification range from 15x to 200,000x and a resolution of 5 nanometers. The Scanning Electron Microscope creates the magnified images by using electrons instead of light waves. A clear view of the micro image can be viewed by magnifying the image. Then capture the image before it is saved to the computer. Figure 3.12 shows scanning electron microscopes and Table 3.7 shows general information about SEM.

Figure 3.12: Zeiss SEM type Evo 50 Series

Table 3.7: General Information of SEM

Machine Specification	
Manufacture and id no	Carl Zeiss / 201737-H
Model No	Carl Zeiss AG - EVO® 50 Series
Resolution	3.0nm @ 30kV (SE and W) 2.0nm @ 30kV (SE with LaB6 option) 4.5nm @ 30kV (BSD - XVP® mode)

CHAPTER 4
RESULTS AND DISCUSSION

This chapter presented results and discussion. Each result will be followed by respective analysis and discussion. Discussion is made in one section which is surface roughness and surface profile. The flow and steps of the analysis are explained throughout this chapter. Factors influencing each response are analysed accordingly.

4.1   Surface roughness

Surface roughness is important as it influences the quality of surface profile, surface appearance, dimensional accuracy, tolerance as well as fatigue strength of the machined components. Many factors contributing to the which surface roughness quality, which include the cutting parameters, cutting conditions, the properties of workpiece material and the properties of cutting tool itself (Aouici et al, 2013). In this study, the surface roughness between dry and wet machining was compared when machining AISI 1045 to differentiate the benefit of their effect during machining.

4.2 Surface roughness data and graph analysis

A statistical analysis was used to determine surface roughness of AISI 1045. Table 4.1 until Table 4.4 show information data for 0.15 mm/rev and 0.50 mm/rev feed rate at dry and wet cutting condition respectively. Surface roughness of every sample was taken using surface roughness tester based on average values. Figure 4.1 until Figure 4.4 show the trend in the surface roughness with varying machining speed when machining of AISI 1045 under dry and wet conditions

4.2.1 Wet Cutting Condition

Table 4.1: Wet cutting with various cutting speed for feed rate 0.15 mm/rev.

| Wet			
Cutting Speed (m/min)	Feed Rate (mm/rev)	Depth of Cut (mm)	Surface Roughness, Ra (μm)
35	0.15	1	3.09
41	0.15	1	3.12
47	0.15	1	3.95
53	0.15	1	3.28
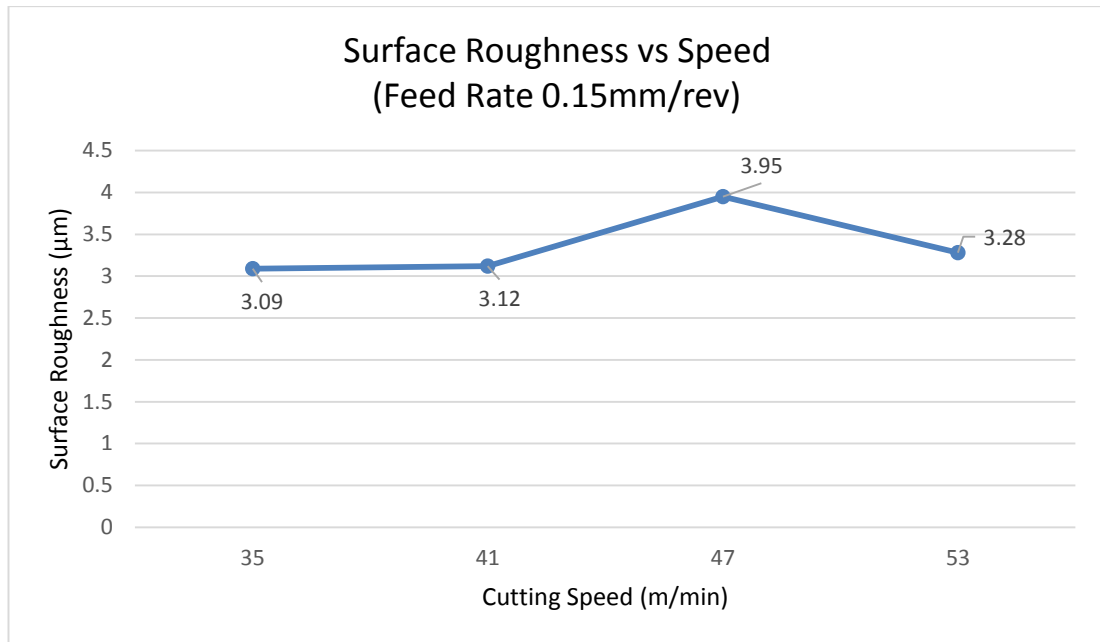
Figure 4.1: Surface Roughness,Ra (μm) Versus Speed (m/min) for wet cutting condition with feed rate 0.15mm/rev

Figure 4.1 shows the line graph of the surface roughness, Ra versus cutting speed at wet condition at different spindle speed with constant feed rate 0.15 mm/rev. At the cutting speed 35 m/min, the value of surface roughness is 3.09 μm then increase until 3.12 at 41 m/min and keep increased gradually to 3.95 μm at 47 m/min. The line graph show that the surface roughness, Ra increase steadily between cutting speed 35 m/min to 47 m/min but there was slightly decrease at cutting speed 53 m/min. According to Chikalthankar et al.,(2014), the surface roughness will increased with an increasing in feed rate and depth of cut but decreased in cutting speed. AISI 1045 carbon steel shows surface roughness decreased started from 47 m/min to 53 m/min of cutting speed.

At cutting speed 35 m/min to 41 m/min which is low cutting speed, the sliding action between cutting tool and workpiece still in perfect condition this is due to the friction and temperature still lower. The cutting tool retain at it shape especially at the nose radius. During cutting process, fine condition will give fine surface roughness. When the cutting speed increase, cutting tool wear and nose radius not in the uniform shape. This condition will slide workpiece at imperfect condition where damage cut will slide the workpiece unbalance cutting force. Tool wear more obvious, temperature increase, friction also increase. On this situation, some phenomena occur, the workpiece

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material start to melt and material will flow side of feed mark. Therefore, this will affect the surface roughness get low value.

Table 4.2: Wet cutting with various cutting speed for feed rate 0.50mm/rev

Wet			
Cutting Speed (m/min)	Feed Rate (mm/rev)	Depth of Cut (mm)	Surface Roughness, Ra (μm)
35	0.50	1	16.33
41	0.50	1	15.77
47	0.50	1	15.02
53	0.50	1	18.07
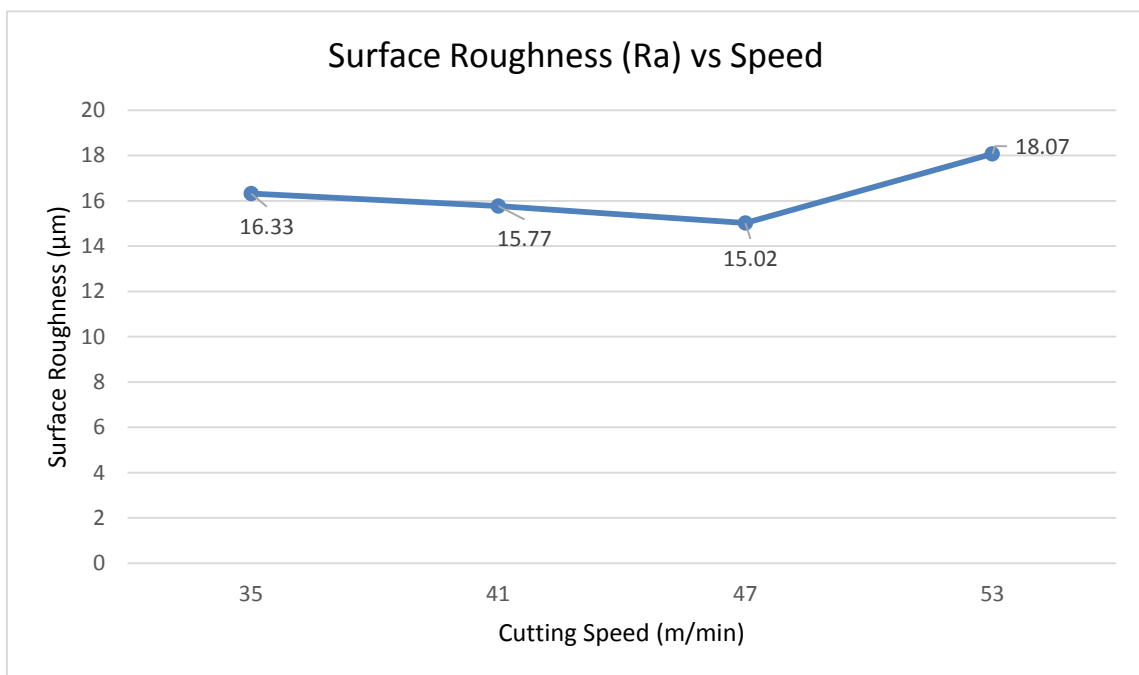
Figure 4.2: Surface Roughness,Ra (μm) Versus Speed (m/min) for wet cutting condition with feedrate 0.5mm/rev

Figure 4.2 shows wet cutting condition at feed rate 0.50 mm/rev with different cutting speed. The line graph shows that the surface roughness, Ra slightly decreased followed cutting speed 35 m/min, 41 m/min, and slightly decrease at cutting speed 47 m/min. At higher cutting speed which is 53 m/min it shows the surface roughness increasing gradually. Thus, surface roughness decreased with the increased of cutting speed. From the graph above, the trending is much better compared to the graph surface roughness for wet cutting condition with feed rate 0.5mm/rev.

However, at higher cutting speed, it shows worse of surface roughness value. At low cutting speed which is 35 m/min, cutting tool retain it nose radius and it can slide very sharp well feed mark and in the end produce low surface roughness. The surface roughness become low as cutting speed increase at 41 m/min. When cutting speed is increase at 53 m/min, surface roughness starts to deteriorate, this is suspected to the high tool wear as the cutting speed increase. When tool wear increase, cutting speed also increase and this situation cannot produce good nose radius due to the workpiece force not stable.

4.2.2   Dry Cutting Condition

Table 4.3: Wet cutting with various cutting speed for feed rate 0.15 mm/rev.

Dry			
Cutting Speed (m/min)	Feed Rate (mm/rev)	Depth of Cut (mm)	Surface Roughness, Ra (μm)
35	0.15	1	3.80
41	0.15	1	3.85
47	0.15	1	5.86
53	0.15	1	4.06
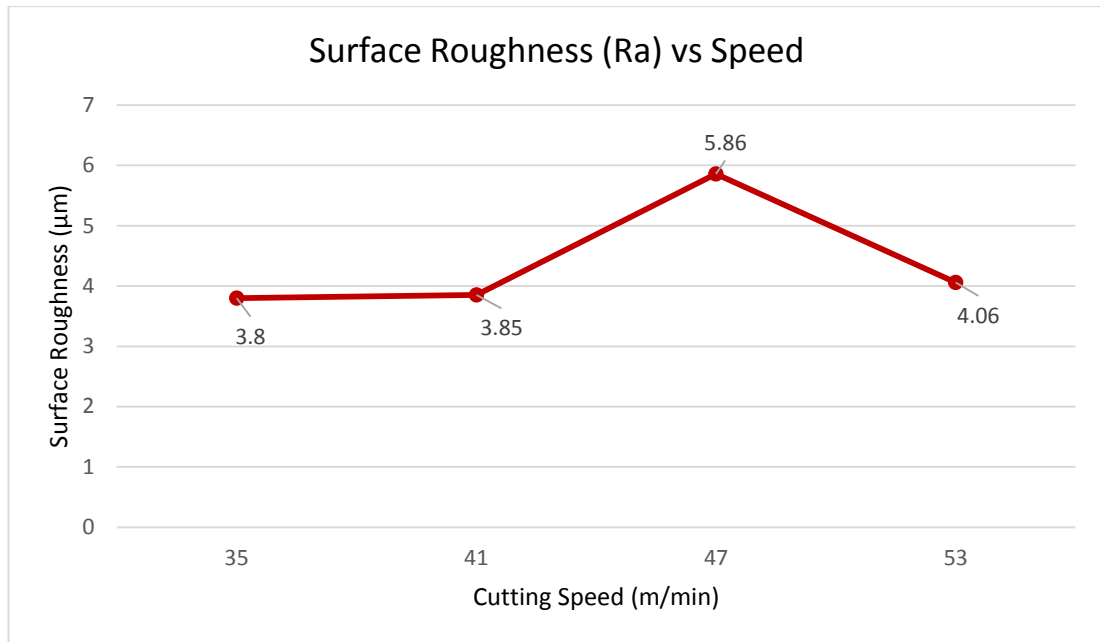
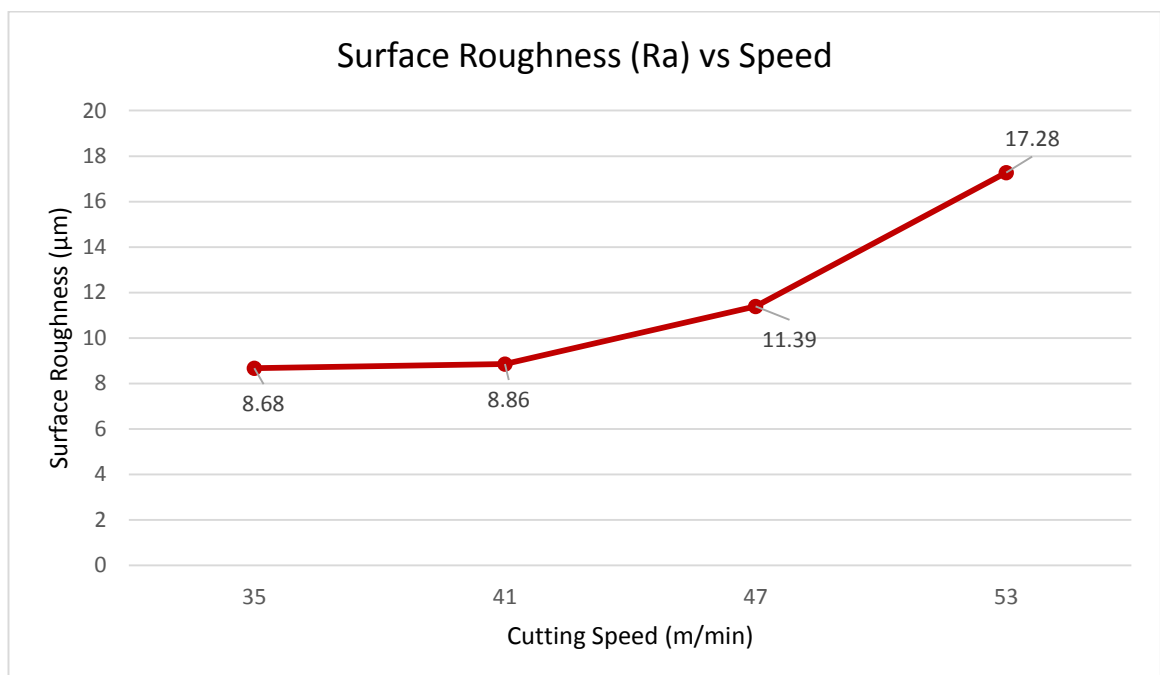Figure 4.3: Surface Roughness,Ra (μm) Versus Speed (m/min) for dry cutting condition with feedrate 0.15mm/rev

From Figure 4.3, the value of surface roughness was 3.80 μm when cutting speed at 35 m/min. When cutting speed increase at 41 m/min, the value of surface roughness slightly increased to 3.85μm and then increase gradually to 5.86μm when the cutting speed was 47 m/min. It was found that the value of surface roughness of AISI 1045 was increased from 3.80 μm to 5.86 μm (35.11%) between cutting speed 35 m/min to 47 m/min. Then, the surface roughness value suddenly decreased from 5.86 μm to 4.06 μm (30.68%) between cutting speed 47 mm/min to 53 mm/min.

It shows at lower cutting speed, temperature low, nose radius is good and can cut naturally. However, when cutting speed increase to maximum 53 m/min, is expected increase in cutting speed, will produce high friction, high temperature, cutting tool should wear, nose radius will not uniform anymore, slide in workpiece is unbalance. This condition contributes to increase the surfave roughness value.

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Table 4.4: Dry cutting with various cutting speed for feed rate 0.50mm/rev

Dry			
Cutting Speed (m/min)	Feed Rate (mm/rev)	Depth of Cut (mm)	Surface Roughness, Ra (μm)
35	0.50	1	8.68
41	0.50	1	8.86
47	0.50	1	11.39
53	0.50	1	17.28

Figure 4.4: Surface Roughness,Ra (μm) Versus Speed (m/min) for dry cutting condition with feedrate 0.5mm/rev

From Figure 4.4, the value of surface roughness was 8.68 μm at cutting speed 35 m/min. As the cutting speed increase to 41 m/min, the surface roughness was slightly increase to 8.86 μm. It shows the surface roughness keep increasing at cutting speed 47 m/min and also at 53 m/min which 11.39 μm and 17.28 μm respectively. The lowest value of surface roughness was obtained at spindle speed 35 m/min while the highest value of surface roughness was obtained at spindle speed 53 m/min. From the line graph, the value of surface roughness for AISI 1045 was increased as the spindle speed value of dry turning increased at feed rate 0.50 mm/rev. In dry turning operation of

AISI 1045, the surface roughness increased as the feed rate increased. Selvaraj and Chandramohan (2010) in their study stated that this situation is due to the widening in the area of contact and changes in the force per unit length, resulting in great distortion of sticky chip. Hence, it can be said that the lowest value of surface roughness was achieved at low feed rate which was 0.15 mm/rev as compared to the values at high feed rate.

4.2.3 Comparison dry and wet cutting condition

Table 4.5: Data of surface roughness, Ra at dry and wet (Feed Rate 0.15mm/rev)

Wet (Ra)		Dry (Ra)	
Speed (rpm)	Surface roughness (μm)	Speed (rpm)	Surface roughness (μm)
275	3.09	275	3.80
325	3.12	325	3.85
375	3.95	375	5.86
425	3.28	425	4.06
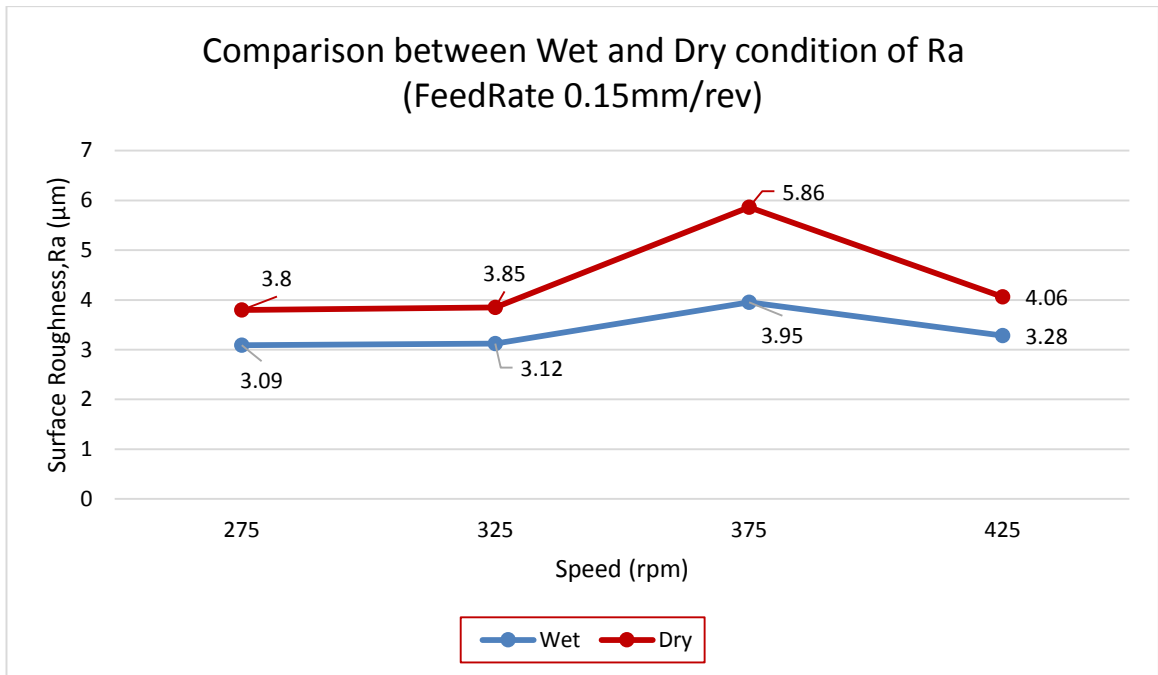
Figure 4.5: Graph comparison of surface roughness,Ra vs speed (FeedRate 0.15mm/rev)

Figure 4.5 shows graph of comparison between wet and dry cutting condition at feed rate 0.15mm/rev. The wet cutting conditions shows the lower surface roughness compare to dry cutting condition. At lower feed rate, wet cutting condition is better than dry cutting condition. This phenomenon occurs due to cutting contribute lubrication and cooling effect. It can retain nose radius and the coolant slide into the workpiece very well.

Table 4.6: Data of surface roughness Ra at dry and wet (Feed Rate 0.50mm/rev)

Wet (Ra)		Dry (Ra)	
Speed (rpm)	Surface roughness (μm)	Speed (rpm)	Surface roughness (μm)
275	16.33	275	8.68
325	15.77	325	8.86
375	15.02	375	11.39
425	18.07	425	17.28
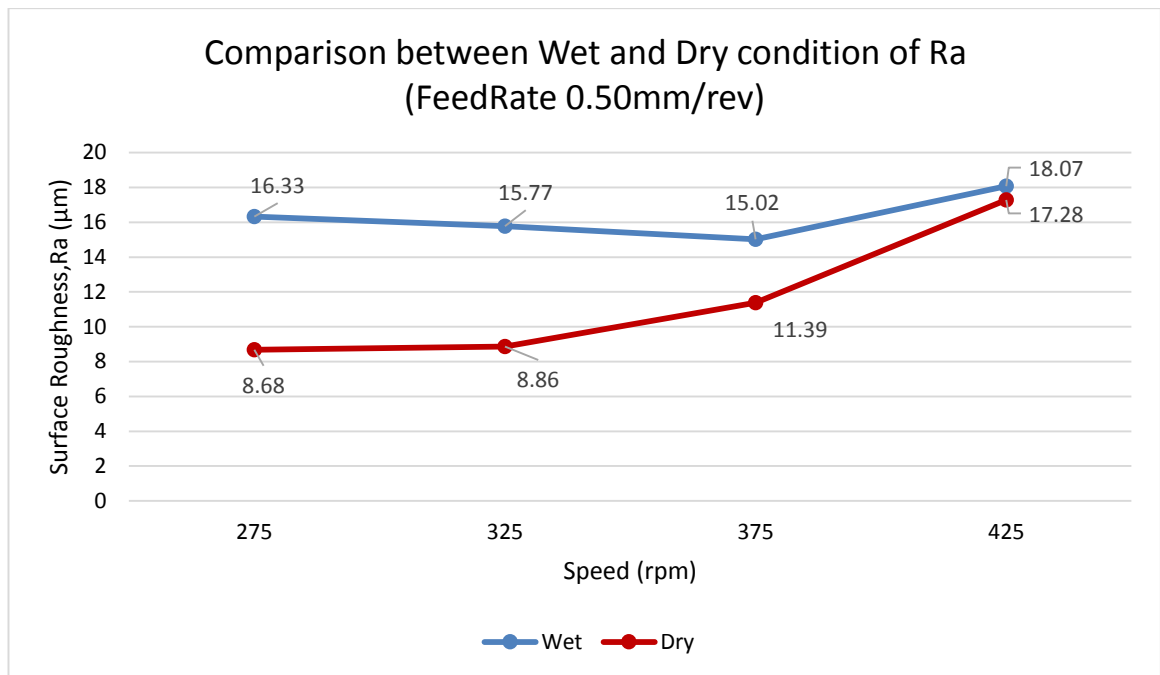
Figure 4.6: Graph comparison of surface roughness, Ra vs speed (Feed Rate 0.50mm/rev)

Figure 4.6 shows both results of surface roughness in wet and dry condition at feed rate 0.50mm/rev. From the graph it shows that as the feed rate increase, dry cutting better than wet cutting, this situation occurs because of at the higher feed rate, the force moves fast and give high pressure between cutting tool and workpiece will restrict the penetration of the cooling. Therefore, on this time, the coolant provides small cooling action and shift the chips away from the cutting region. This phenomenon demonstrate that cutting fluid did not show a significant effect to the surface finish. The use of cutting fluid just benefitted the machining performance in terms of chip removal in order to avoid them entangled with the cutting tool. This results is consistent with Yahya, 2010, where he found that the cutting fluid did not give a big impact on surface roughness during the machining trial on effect of cutting fluids in turning AISI 1045 steel with coated carbides tool.

4.3 Surface Profile

Table 4.7: Surface Profile for feed rate 0.15 mm/rev at Dry and Wet condition.

FEED RATE 0.15 mm/rev		
CUTTING SPEED	DRY	WET
35		
41		
47		

| 53 | | |
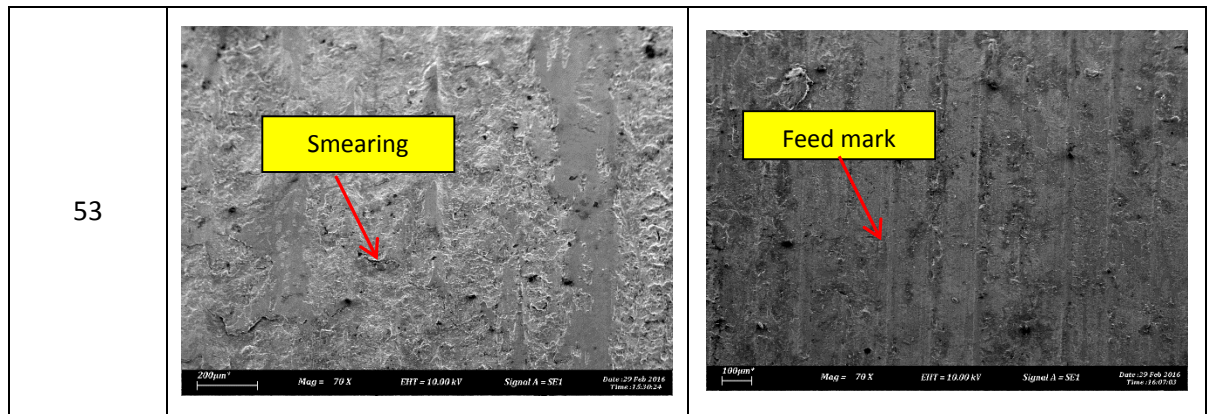
Table 4.7 until Table 4.8 shows the micrograph of surface under wet and dry cutting with various cutting speed by using Scanning Electron Microscope. From the results, the surfaces produced are still considered to be well-defined of the feed mark that occur in the form of peak and valley profile. At dry cutting, it shows that fine feed mark occur. For example, at cutting speed 34 m/min and 41 m/min. In general, it can see at low cutting speed, fine surface profile demonstrated on machining surface, it can observed fine feed mark peak and valley which reflected smooth and shiny surface after machining. As the cutting speed increase some of the image shown obviously differentiation between peak and valley where the image of peak seems higher as compare to the lower cutting speed. This could be due to tool wear that come from the uneven action from the ununiformed nose radius.

There are also evidence of material slide flow for smearing surface due to the molten workpiece material resulting from high cutting temperature. This evidence can see at cutting speed 53 m/min at dry condition. Even surface roughness demonstrate lower surface roughness value, but surface profile demonstrate deteriorate surface condition which is showing that the surface is not in fine condition. Therefore, the use of cutting parameter in this condition is not recommended.

In wet cutting condition, it shows the surface profile are fine feed mark and shows smooth surface finishing due to the cooling action from coolant. The surfaces generated under the conditions investigated were well-defined and free from other damage such as cracking, tearing and rupture that are detrimental to machined components.

Table 4.8: Surface Profile for feed rate 0.50 mm/rev at Dry and Wet condition.
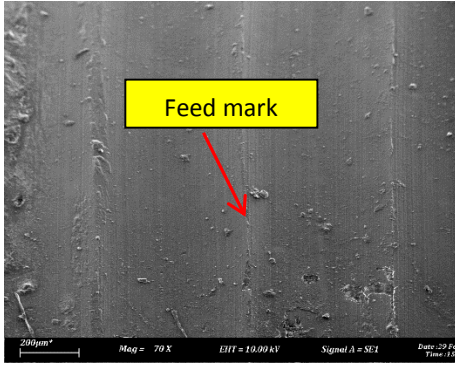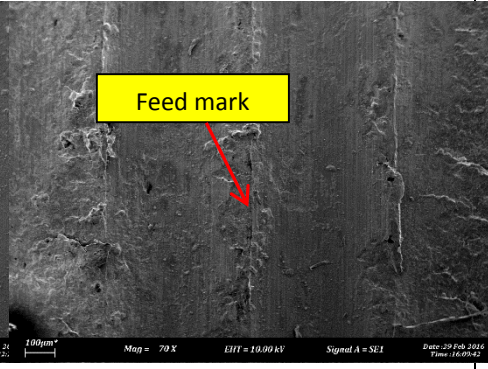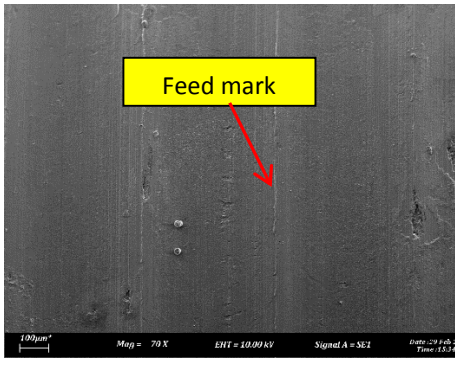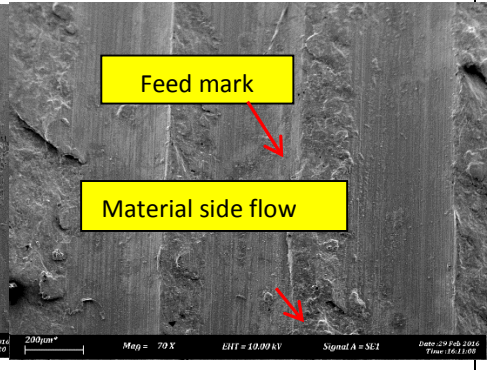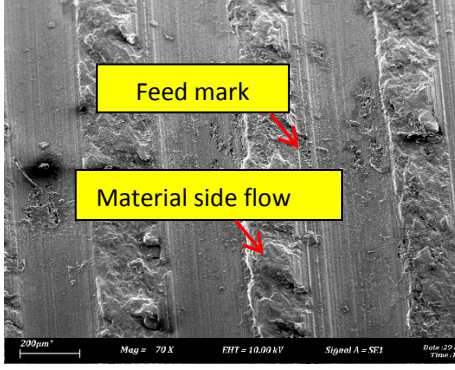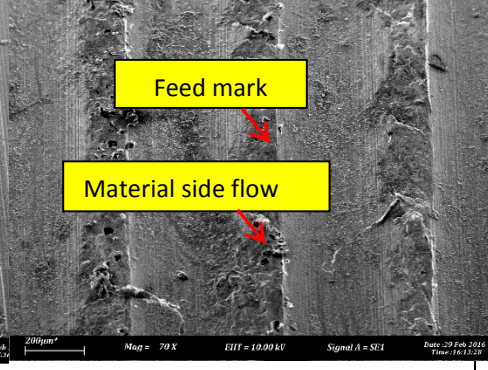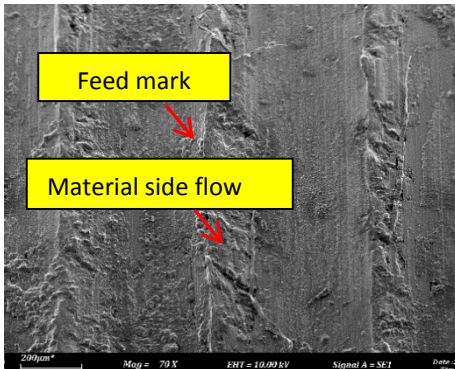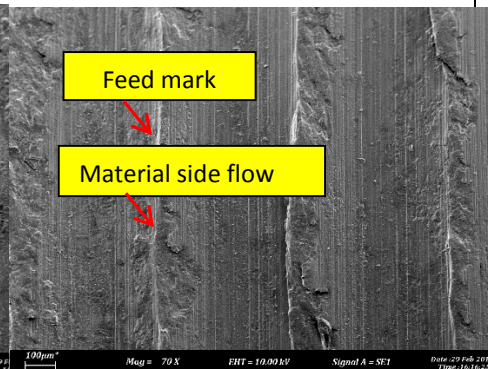
| CUTTING SPEED | FEED RATE 0.5 mm/rev | |
	DRY	WET
35		
41		
47		
53		

Figure 4.8 shows the results of surface profile at dry and wet condition at feed rate 0.5 mm/rev. At dry cutting condition, the feed mark shows very fine and smooth at the cutting speed 35 m/min and 41 m/min. But as the cutting speed increase at 47 m/min, there are evidence of surface deteriorate at the half side of the feed mark. This phenomenon occur probably due to worn region at the edge of the cutting tool.

Overall at low feed rate of 0.15 mm/rev, the surface roughness increase as the cutting speed increase. Whereas at high feed rate 0.50 mm/rev, the surface roughness demonstrate constant surface roughness value as the cutting speed increase. This indicate there are evidence of crater wear. Crater wear usually occur due to the heat at rake face diffusion of work materials. This material side flow that occur at cutting speed 47 m/min, will give effect to the strength of the workpiece in fatigue condition, it will ease for the crack may happened. This situation consistently occurred at higher cutting speed which is 53 m/min.

At wet condition, it shows the surface does not produce a fine and smooth surface. As the cutting speed increasing, the surface profile shows condition of material side flow. Material side flow is one of the phenomena that deteriorate the machined surface. It is defined as the displacement of a workpiece material in a direction opposite to the feed direction, such burrs that elongates at the side of feed marks ridge. During machining, the material side flow occurred when the sheared workpiece materials plasticised as the results of high cutting temperature, and on the same time the cutting tool push aside that material to form such a deformed layered mark at the side of feed mark ridge (Mohan et al. 2010).

CHAPTER 5

CONCLUSION

5.1 Conclusion

This project presents the experimental evaluation on machinability of AISI 1045 under dry and wet condition. From the machining data obtained, the conclusions can be drawn. At lower feed rate at 0.15 mm/rev, wet cutting produce better surface roughness compare to dry cutting. Minimum surface roughness is 0.39 μm for wet whereas minimum surface roughness for dry is 3.8 μm. However, at high feed rate at 0.5 mm/rev, the surface finish for dry is better than wet. Minimum surface roughness for dry is 8.6 μm whereas minimum surface roughness for wet is 15.02 μm. The effect of cutting fluid can be negligible at high feed rate at 0.5

In terms of the surface profile, its shows for both dry and wet appear to be feed mark according to the nose radius. However, the feed rate for 0.5 mm/rev is wider due to the higher value. There are evidence of material side flow, metal detachment and deteriorate surface finish at some area at the surface. There are also the evidence of side worn along feed mark due to the worn surface of cutting tool.

Surface roughness is definitely has a strong influence on the quality of the end product. The surface roughness of any materials therefore needs to be controlled well in any machining processes. The benefits that can be obtained from the controlled surface roughness are cost can be reduced and better quality control.

5.2 Recommendation for Future Work

There are few recommendations provide as to extend understanding of fundamental in surface roughness, as well as to improve the machining process in order to gain a better surface finish and gain more information about surface roughness with the different conditions use while machining are;

a) The experimental work in this project has focused only for material Carbon Steel AISI 1045. It is recommended that further research be conducted for a variety of material such as Aluminium and Mild Steel.

b) The result shows the cutting fluid did not give a big impact on the surface roughness, it may be interesting to conduct this research by using another coolant types and the volume of coolant may be change.

c) Finally, the project analysed is focus on surface roughness, further analysed should be carried out for chip formation, cutting force and tool wear.

5.3 Sustainable Development

Sustainable manufacturing consists of environmental protection, profitability and societal benefit for all industrial areas. Manufacturing practices are investigated for optimize production efficiency while minimizing environmental impact and maintaining social equity (Jayal *et al.*, 2010). It can be achieved through changes in products, processes and systems related to the sustainability issues. To improve the sustainability of machining processes researchers are making efforts to eliminate or reduce the use of cutting fluids during machining through several means: development of improved tool coatings, materials and cutting fluids, hybrid machining processes and process optimization.

There are two main stages for sustainable development in this research:

a) Scrap steel and chips
b) Coolant usage

5.3.1 Scrap steel and chips

Steel's durability allows for the reuse of countless products, which is enhanced through proper design. The main sources of recycled steel called steel scrap: excess material from steel production. 100% of scrap from steel production is collected and recycled directly into steel production. Thus, the AISI 1045 steel scrap can be recycled fully to reduce useful materials going to landfill sites as waste. Furthermore, the minimum bar length is needed to ensure a rigid clamping in the chuck of the CNC lathe considered as bar scrap was also can be recycled for remanufacturing. It involves the disassembly of a product, during which each component is thoroughly cleaned, examined for damage and either reconditioned to original equipment manufacturer specifications or replaced with a new part. Many steel products lend themselves to remanufacturing, taking advantage of the durability of the steel components (Lund. R, 1993).

5.3.2 Coolant usage

Sustainability performances for the coolant or lubricant should be particularly taken into account. The coolant used can be recovered in order to reduce occupational and environmental hazards. Completing avoidance of cooling lubrication in metalworking will not be possible without deductions in tool life or surface quality. However the wet cutting condition not always efficient especially in high feed rate machining. Thus, it is necessary to redesign the machining condition in order to minimize the coolant usage. This mechanism is called minimum quantity lubrication (MQL). During machining in small quantities, these tools are feed into cutting zone (Fratila, D., 2009). The minimization of cutting fluid also leads to economic benefits by way of reducing lubricant costs and workpiece, tool or machine cleaning cycle time. MQL can reduce the corner and flank wear more effectively than a solution type of cutting fluid, reduces or eliminates problems associated with thermal shocking of the cutting tool and reduces both cost of buying and disposing of conventional cutting fluid if all operations can be run with MQL (Thamizhmanii, S., 2009).

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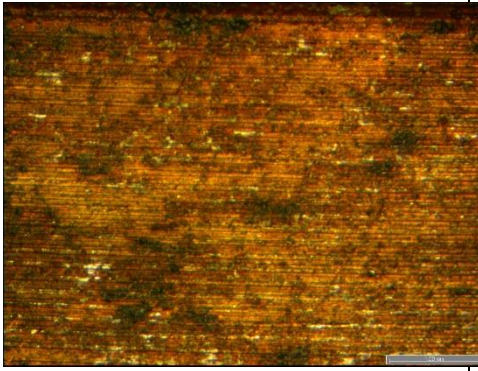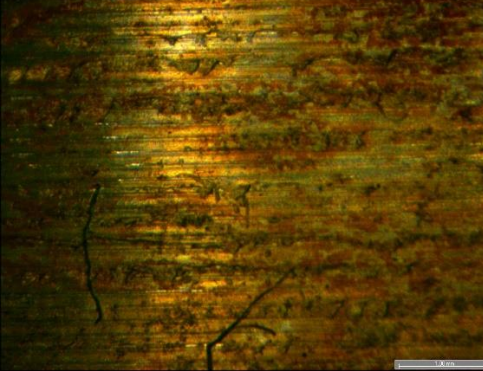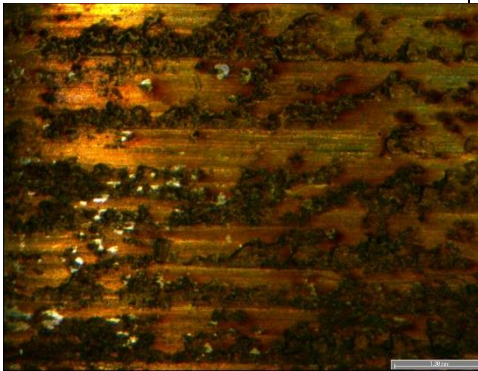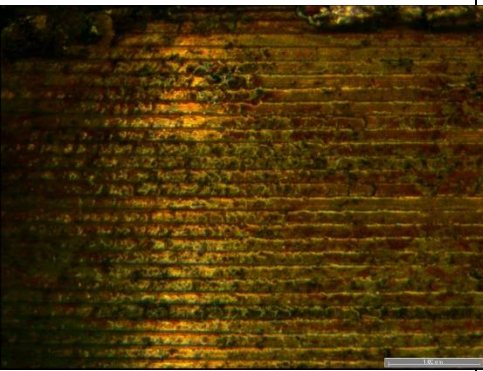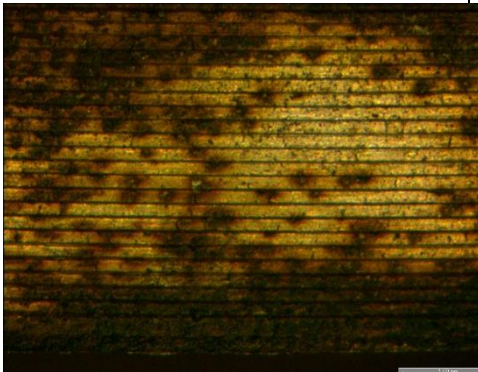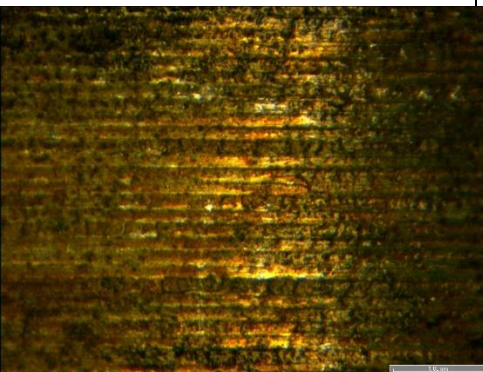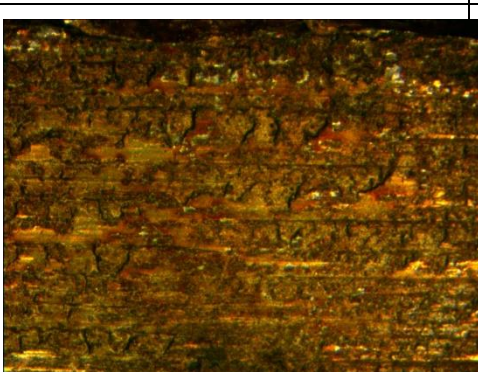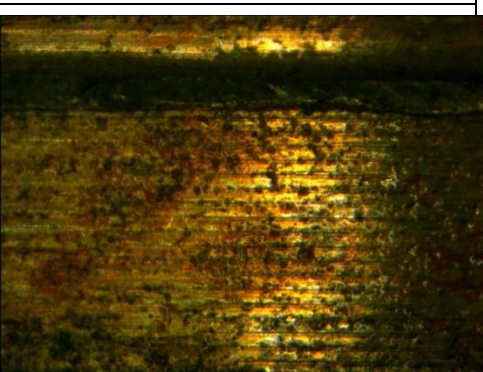
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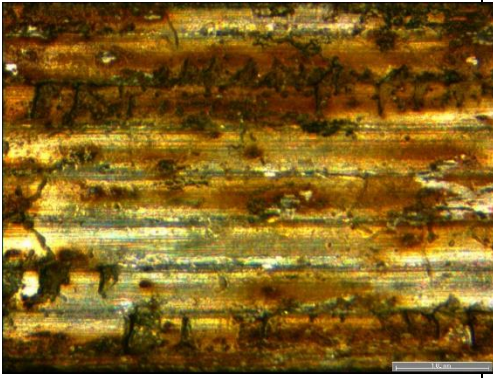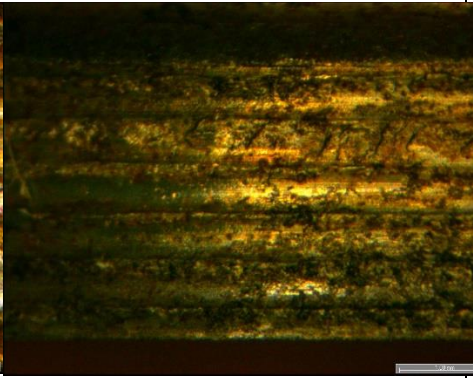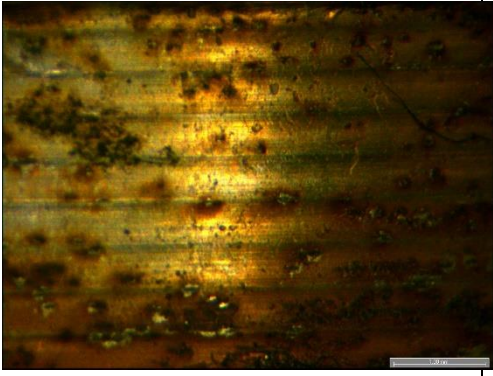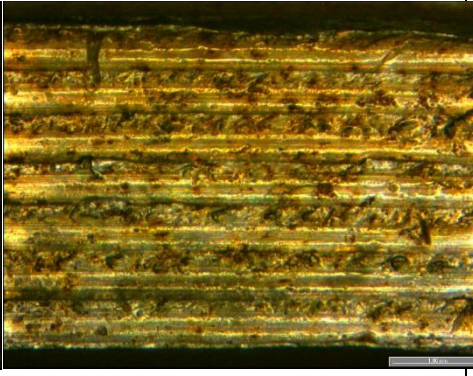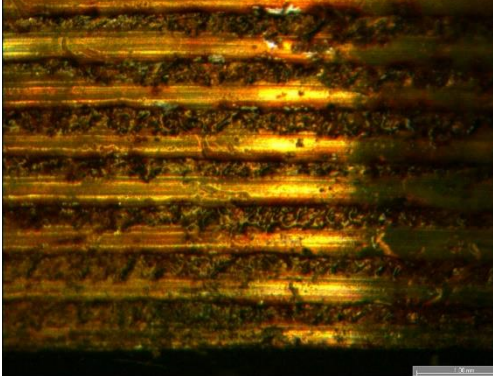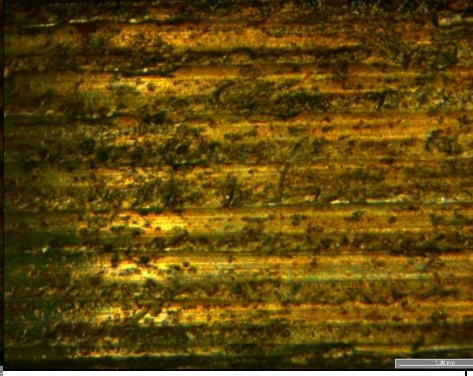
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Figure of Surface Profile under Stereo Microscope using 1.5x magnifivcation

FEED RATE 0.15 mm/rev		
CUTTING SPEED	DRY	WET
275		
325		
375		
425		

FEED RATE 0.5 mm/rev		
CUTTING SPEED	DRY	WET
275		
325		
375		
425		