COMPARATIVE STUDY OF PERFORMANCE DIFFERENCE GEOMETRIES CARBIDE TOOL IN TURNING TITANIUM ALLOY TI-6AL-4V ELI

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

by

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DECLARATION

I hereby, declared this report entitled “COMPARATIVE STUDY OF PERFORMANCE DIFFERENCE GEOMETRIES CARBIDE TOOL IN TURNING TITANIUM ALLOY TI-6AL-4V ELI” is the result of my own research except as cited in references.

Signature : ………………………………………

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Date : 21 JUNE 2024

APPROVAL

This report is submitted to the Faculty of Industrial and Manufacturing Technology and Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Hons). The member of the supervisory committee is as follow:

………………………………………………………

(Associate Professor Dr. Mohd Amri Bin Sulaiman)

ABSTRAK

Aloi titanium Ti-6Al-4V ELI mempunyai nisbah kekuatan kepada berat yang baik, ia digunakan secara meluas. Dalam pemotongan logam, elemen penting yang mesti dipertimbangkan ialah geometri alat pemotong. Alat pemotong karbida digunakan secara meluas dalam proses pemesinan untuk pelbagai jenis logam dengan geometri karbida yang sesuai. Kertas kerja ini membentangkan mekanisme kegagalan alat yang diperiksa, corak haus dan jangka hayat alat CNC memutar Ti-6Al-4V ELI dengan membandingkan dengan tiga geometri sisipan perbezaan: rombik 80˚, rombik 35˚, dan trigon 80˚. Gabungan parameter disusun seperti kelajuan pemotongan dengan julat 90 hingga 150 m/min, kadar suapan dengan 0.1 hingga 0.2 mm/rev, dan kedalaman potongan dikekalkan pada 0.4 mm. Mikroskop tiga paksi digunakan untuk mengukur haus rusuk bagi setiap 20 mm pada bahan kerja dengan mengambil 5 nilai haus rusuk bagi setiap parameter gabungan untuk tiga perbezaan geometri karbida. Daripada keputusan yang diperolehi, didapati rombik 80˚ menghasilkan hayat alat yang lebih lama dan menunjukkan kelajuan pemotongan dan kadar suapan yang paling rendah menyebabkan hayat alat yang lebih lama. Kadar suapan optimum ialah 0.2 mm/rev, dimana hayat alat yang boleh diterima diperolehi untuk tiga perbezaan geometri. Berdasarkan keputusan, alat karbida 35˚ rombik menyebabkan kadar haus tertinggi. Tindak balas optimum diperolehi pada kelajuan pemotongan 120 m/min kelajuan pemotongan dengan kadar suapan 0.2 mm/rev yang diperoleh untuk sisipan 80˚ rombik. Dengan menghubungkan operasi mesin dan lengkung hayat alat yang diperoleh menggunakan data haus rusuk, tingkah laku haus alat pemotong geometri untuk karbida tidak bersalut telah diterangkan. Daripada penyelidikan ini, walaupun aloi titanium, Ti-6Al-4V ELI dianggap sebagai bahan dengan kebolehmesinan yang rendah, terdapat geometri karbida yang sesuai untuk memberikan jangka hayat alat yang paling lama sekali gus mengurangkan kos pemesinan.

ABSTRACT

Since titanium alloy Ti-6Al-4V ELI has a good strength to weight ratio, it is utilised extensively. In metal cutting, one of the important elements which must seriously consider is geometries of cutting tools. Carbide cutting tool is widely used in machining process for various metal types with suitable geometries carbide. This paper presents the mechanism of tool failure, the wear pattern and tool life of the CNC turning Ti-6Al-4V ELI by comparing it to three type of carbide tool geometry: rhombic 80˚, rhombic 35˚, and trigon 80˚. The combination of parameter is arranged such as cutting speed with range of 90 to 150 m/min, feed rate with 0.1 to 0.2 mm/rev, and depth of cut was kept constant at 0.4 mm. A three-axis microscope was used to measure the flank wear for every 20 mm on the workpiece with 5 value of flank wear for each combination parameter for three type of carbide tool geometry. From the result obtained, it is found that the rhombic 80˚ resulted in longer tool life and show that the lowest cutting speed and feed rate resulted in longer tool life. The optimal feed rate was 0.2 mm/rev, with which a tolerable tool life was obtained for three difference geometry. Based on the result, the rhombic 35˚ carbide tool caused the highest wear rate. The optimum responses are obtained at cutting speed 120 m/min cutting speed with 0.2 mm/rev feed rate that obtained for 80˚ rhombic insert. By linking the machine operations and the tool life curves obtained using flank wear data, the wear behaviour of geometry carbide tool for uncoated carbide was described. From this research, even though titanium alloy, Ti-6Al-4V ELI is considered as material with low machinability, there are suitable geometry carbide available to give out the longest tool life thus reducing machining cost.

DEDICATION

My beloved father, Abdul Mua'in Bin Mohamed Junus

My pretty mother, Zuriawati Binti Mohamad Daud

My brother and sister, Aniq, Fatin, Aisyah and Hazim

My supporter, Nur Atyhirah

For giving me moral support, cooperation, understanding, and accompanying me along the difficult pathway in my university life

Thank You So Much

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In the Name of Allah, the Most Beneficent, the Most Merciful'

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LIST OF ABBREVIATIONS

ELI - Extra Low Interstitial
CNC - Computer Numerical Control
PC - Personal Computer
CBN - Cubic Boron Nitride
MRR - Material Removal Rate
CVD - Chemical Vapor Deposition
DOC - Depth of Cut
OSHA - Occupational Safety & Health Regulations
CO2 - Carbon Dioxide
AHP - Analytical Hierarchy Process
Ti - Titanium
ISO - International Organization for Standardization
MMCs - Metal-Matrix Composites
BUE - Build-Up Edge
DOE - Design of Experiment
RSM - Response Surface Methodology
PSM - Project Sarjana Muda
Vb - Flank Wear
Vb max - Flank Wear Maximum
Vb avg - Flank Wear Average
Vc - Cutting Speed
f - Feed Rate

LIST OF SYMBOLS

cm	-	Centimetre
m	-	Metre
%	-	Percent
mm/rev	-	Millimetre per Revolution
mm	-	Millimetre
MPa	-	Mega Pascal
GPa	-	Giga Pascal
°	-	Degree
r_ε	-	Corner Radius
HB	-	Brinell Hardness
nm	-	Nanometre
kg/m^3	-	Kilogram per cubic metre
Wt%	-	Percentage Weight
J/gK	-	Joules per gram per Kelvin
kg	-	Kilograms
mm/min.	-	Millimetre per minute
rpm	-	Revolution per minute
kN	-	Kilo newton
L	-	Litre
W/m/K	-	Watts per meter per Kelvin
T	-	Thickness
m	-	Mass
v	-	Volume
L/min	-	Litre per Minute
kW	-	KiloWatt
N	-	Newton

CHAPTER 1

INTRODUCTION

This chapter provides a short introduction of the project background on "Comparative Study of Performance Different Geometries Carbide Tool in Turning Titanium Alloy Ti-6Al-4V ELI". Furthermore, this chapter will explain the background information, problem statement and objective, scope of project and organization of report.

1.1 Background Information

Titanium alloys are regarded as significant important in engineering materials for industrial applications because of their excellent corrosion resistance, high temperature adaptability and good strength to weight ratio. The aerospace and aircraft industries have made extensive use of titanium alloys because of their remarkable strength and high corrosion resistance at high temperatures. Hence, high cutting temperature often results in severe tool wear, such as plastic deformation, chipping, and fracture at the cutting edge (Che Haron, 2001). As an effect, the tool will be worn out very quickly and thus a poor surface finish will be produced. This research study focuses on the high-speed turning of Ti-6Al-4V ELI titanium alloys utilizing a 3 difference geometries uncoated tungsten carbide insert. The aims are to investigate the wear behaviour and mechanisms of tools on the different values of cutting speed, different geometries tool, and surface integrity of the machined material under dry conditions. This research is performed under dry conditions by using 3 different geometries carbide tools.

The research presented here presents a cost-effective dispensing technique that reduces carbide tool wear and tool life. The anticipated result of this study is crucial since it helps to improve titanium alloy's machinability, increase productivity while maintaining the high caliber and dimensional accuracy of metal products and parts.

1.2 Problem Statement

Titanium alloys have a low heat conductivity, heat produced during machining accumulates close to the machining zone. Then, thermally linked wear mechanisms like adhesion and diffusion wear are more likely to occur in cutting instruments. The modern manufacturing industries are facing obstacles in producing better-quality goods in terms of surface finish, tool life value, tool wear resistance and machining economy for increasing product life. The pattern of tool wear performance, and tool life can all be enhanced by selection type of geometry insert in CNC machining in order to determining the best output or quality of the product. The impact of difference geometries insert in machining towards tool life value and tool wear progression will be focusing in this project.

In all machining conditions, tool wear is inevitable; nevertheless, the tool lifespan varies depending on the carbide geometry. It need not always be the most expensive or the same tool that was used for the job the previous time. (Geusen-Nytsch, 2005). This means that in order to comprehend the relationships between tool wear performance and machining parameters, it is necessary to characterize a particular combination of cutting tools and workpieces. The impact of difference geometry insert towards tool life value and tool wear progression will be study in this project.

1.3 Objective

The objectives are as follows:

I. To investigate the performance of tool life value on difference geometries un-coated carbide cutting tools.
II. To analyze tool failure mode and tool wear pattern on the cutting tool during turning titanium alloy Ti-6Al-4V ELI under dry conditions.

1.4 Scope of Project

There are various ways to accomplish the project's goal; a computer numerical control (CNC) lathe machine is used for the project's turning operation. Titanium alloys are used in a wide variety of lightweight application in energy, aerospace and chemical industries due to strong mechanical properties and outstanding corrosion resistance in combination with high strength-to-weight ratios of materials. To carry out the process, 3 difference uncoated tungsten carbide with difference geometries (CNGG 120408, VBMT 160404, and WNMG 080408) has been selected. The project to investigate the tool life value and tool wear progression on tool performance was carried out using various difference geometries under dry conditions. The cutting parameter considered the constants depth of cut (0.4 mm), cutting speed (90, 120 and 150 m/min), and feed rate (0.1 and 0.2 mm/rev) of cutting. Next, a CNC lathe machine will be used to determine the tool's life duration based on the scope mentioned above.

1.5 Organization of Report

Chapter 1 covers the introduction of this project. It contains the background information, problem statement, objective, scope of project and organization of report.

Chapter 2 covers the literature review of this study. It contains a literature review about turning machining, dry machining condition, different geometries carbide and tool performance.

Chapter 3 covers the methodology of this project. It contains flow chart, literature review and experimental work design.

Chapter 4 contains the results and discussion for this research. The data from this study is tabulated and analysed.

Chapter 5 about the conclusion of this research and recommendation for improve the future of lathe machining.

CHAPTER 2

LITERATURE REVIEW

This chapter provides an overview of the project's definitions and information, including project specifications. To comprehend the concept and important details or experience of the project, the theory, evidence, and facts are acquired from a variety of sources. Each and every piece of material has been taken from a variety of sources, including books, journals, and articles.

2.1 CNC Lathe Machine

A workpiece fixed to the rotational axis can undergo a variety of operations on a lathe. Typically, they work in the glass, metal, and woodworking sectors. Drilling, threading, turning, grooving, and parting are typical lathe operations. Traditional lathes move a cutting tool with the use of manual gears and levers. Machinists must keep an eye on their digital readout equipment or indicators while simultaneously moving the cutting tool. A small number of tasks are semi-automatic, even though the majority need human participation. A CNC (Computer Numerical Control) machine, on the other hand, is more dependable and accurate than a traditional lathe. CNC machines are able to make items more accurately and quickly by using modern encoders and motors. A CNC lathe will follow the high precise instructions of G-code to perform the operation.

According to (Azeez et al., 2019) Computer Numerical Control (CNC) and conventional lathe machine that are two categories of lathe machines. It's important to note that conventional lathe machines are a common family member of lathe machines that have been in use for decades and will be for years to come because of their functionality, which makes them impossible to fully eradicate.

2.2 Turning Process

Turning is a machining technique used to removing undesirable material to create rotating pieces. As turning is actually a material removal technique that includes feeding a cutting tool into a work item as it is rotating to give it shape. A turning machine or machine, a work component, an installation, and a cutting instrument are required for the turning method. The work piece is a small piece of pre-formed material that is allowed to pivot at high speeds and is fastened to the installation, which is attached to the turning machine. The cutter is a single-point cutting device that is fixed inside the machine. To create the desired shape, the cutting tool feeds into the rotating work piece and removes material in the form of tiny chips Chauhan D. et al. (2015). Figure 2.1 shows the procedure of turning process.

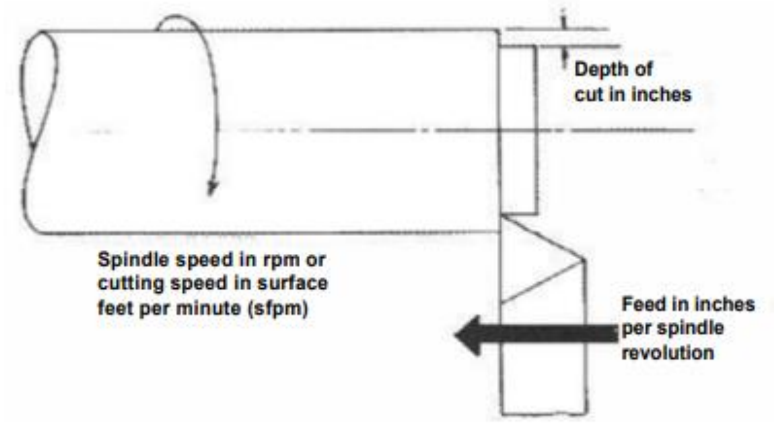


Figure 2.1: Turning procedure

When turning machines are prepared for PC control, they are referred to as computer numerical control (CNC) machines. CNC machines offer excellent accuracy and may pivot the workpiece and move the cutting apparatus based on pre-customized requirements. The combination of turning machines will keeps the same essential parts that allow the workpiece to be turned and the slicing tool to be sustained into the workpiece.

2.2.1 Hard Turning

Hard turning is done with a variety of tipped or solid cutting inserts (ideally CBN) on materials whose hardness falls between 45 and 68 Rockwell. Hard turning can generate an even better surface finish at far greater material removal rates than grinding, even though grinding is known to produce good surface finishes at relatively high feedrates. When hard turning, the ideal mix of insert nose radii, federate, or innovative insert technology will result in a higher surface quality. Instead of requiring many grinding setups, a single configuration may handle multiple hard turning operations. (Bartarya G., Choudhury S.K. 2012). Figure 2.2 are grinding versus hard turning. This will helps hard turning attain great precision as well.

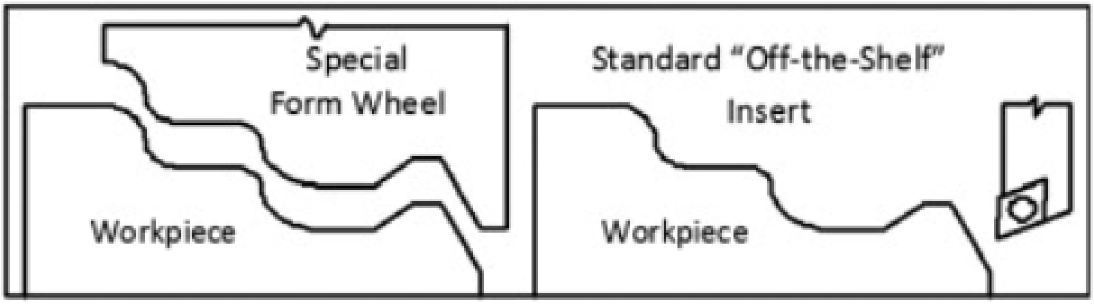


Figure 2.2: Grinding versus hard turning

Compared to multipoint cutting tool grinding, hard turning offers the option of utilising a single point cutting tool. (S.M. Ravi Kumar, Suneel Kumar Kulkarni, 2017). Hard turning allows for the machining of more intricately formed features. Grinding requires a far greater energy and cycle time per unit volume of removed metal than hard turning. Hard materials are often turned using a lathe machine for rough cutting, followed by heat treatment and grinding for finish machining.

2.3 Titanium Alloy Ti-6Al-4V ELI

The surface of Ti-6Al-4V ELI alloy are acceptable and free from any physical damage such as tears and cracks when machined with coated cemented carbide tools (Ibrahim G. A., Ghani J. A., Che Haron C. H, 2009). Titanium alloys are materials that made up of titanium and other chemical elements. These alloys have very high tensile strength and toughness, even at very high temperatures. They can tolerate high temperatures, are strong and lightweight, and offer outstanding resistance to corrosion.

Titanium alloy Ti-6Al-4V also known as Grade 5 titanium, not to be confused with Ti-6Al-4V-ELI (Grade 23). It is made up of 6% aluminium, 4% vanadium, 0.25% (maximum) iron, 0.2% (maximum) oxygen, and the rest is pure titanium. The difficulty of the extraction process and the difficulty of melting during processing or refinement make titanium alloy more expensive than other materials. While titanium alloys have low cutting-edge heat conductivity, they enhance the temperature. Further to that, it possesses strong chemical reactivity, similar to many cutting tool products. As a result of the high cutting temperature and the tight fit between the tool and the workpiece, the tools are especially easy to wear.

2.3.1 Application of Titanium Alloy

Based on Noor Danish et al. (2022), a usage for military applications, spacecraft, aviation, medicines, offshore industry, and highly stressed parts like supercar connecting rods, as well as different luxury sporting equipment and consumer electronics, is made possible by the high cost of both raw materials and processing. Milling procedures are necessary to attain the necessary tolerance limits for titanium alloy (Ti-6Al-4V) material used in aerospace structural components. While finish machining titanium alloys under dry machining circumstances, the most important task is selecting the best machining settings to achieve the desired surface quality and longer tool life. Dry machining typically results in extremely high cutting temperatures and cutting forces (tangential and feed forces), which have an impact on tool life and surface quality.

According to (Juliadmi D., Fajri H., Nuswantoro N. F., Affi J., 2020), titanium alloy also used in biomedical applications due to fulfil the prerequisite of the bone implant. Titanium alloy have good mechanical properties to fulfil the biomedical application such as high strength, low elastic modulus, and high corrosion resistance.

2.4 Cutting Parameter

For the turning procedure, some researchers utilise a high-strength stainless steel tool coated in tungsten carbide. In a number of articles, the turning input parameters included cutting speed, feed rate, depth of cut, and tool wear; the turning output parameters included surface roughness, cutting forces, tool wear, and MRR Muniyappan K. et al. (2023).

In a turning process, there are three significances parameter that are use such as cutting speed feed rate and depth of cut. Rao C. J. et al. (2013) Stated that cutting force is significantly impacted by the interaction between feed and depth of cut along with by the interaction of all three cutting parameters; however, no noticeable impact is observed for surface roughness. The cutting insert manufacturer's recommended cutting parameter values do not account for these limitations. Constraints create the framework for optimising the capabilities of the manufacturing system, particularly those of tools and machine tools, while meeting the requirements of surface quality and dimensional accuracy (Trifunovic M. et al., 2023)

2.4.1 Feed Rate

According to Choun D. et al. (2023) feed rate of 0.15mm/rev are applied on S45C steel in the dry turning process using the CVD coated carbide inserts. Feed rate is essentially the distance covered by the tool in a single spindle revolution. Feed rate is one of parameter that have been tested in turning process.

2.4.2 Cutting Speed

Cutting speed is the speed at which a tool cuts the work, commonly measured in feet per minute. Based on Babe I. B. et al. (2023) the cutting speed that use on stainless steel 316 material is 70 – 170 m/min. Regarding to the experiments carried out at cutting speeds are increase, the cutting temperature also increased Yildirim et al. (2020).

2.4.3 Depth of Cut

The depth of cut (DOC) is most important parameter that needed to consider in turning process. As the depth of cut increase from 0.5 to 1.0 mm is optimum for the lowest value of tool life (Babe I. B. et al., 2023). Chaubey S. K., Gupta K., et al. (2023) found that the high flank wear has been observed with increasing depth of cut.

2.5 Dry Machining

In simple terms, dry machining is a machining process that not use any cutting fluids. The principle of dry machining has been applied in production for a considerable time such as dry turning and dry milling. Dry machining is ecologically desirable and is considered a necessity for manufacturing enterprises (Bedada B. D., Woyesssa G. K., et al., 2021). Considering there is typically more friction and adhesion between the chip and the tool during dry cutting operations, there are higher temperatures, higher wear rates, and ultimately shorter tool life (Yildirim et al., 2020).

Dry machining is environmentally necessary and it will be measured as a requisite for manufacturing company in the near future. The manufacturing industries will be required to consider dry machining condition to implement environment protection laws for occupational safety and health regulations (OSHA). Based on Bagaber S. A., Yusoff A. R. (2017) terms of productivity, the machining process needs to give priority to product sustainability by creating an innovative approach that has the least negative effects on the environment. Concerns regarding energy, health, safety, economical, and environmental factors are inherent in sustainable manufacturing practices. Energy is a major factor in the sustainability of manufacturing. The environment is negatively impacted by it.

Occasionally is research reported on the dry and wet machining of the same material to examine the benefits of dry machining over wet machining, despite the fact that a vast amount of machining research has been done on the dry and wet machining processes independently. Consequently, the purpose of the other research report was to explore the advantages of dry turning over wet turning with regard to surface roughness and machining cost.

The concept of dry machining, which has been suggested by many contemporary researchers, has many advantages such as the potential to apply high cutting speeds and lower cutting forces, which would result in a longer tool life; the absence of harmful effects on people and the environment; the reduction of variable machining costs because there is no cutting fluid; the ease with which a chip that has not been contaminated with cutting fluids can be recycled (Goindi G., Sarkar P., 2017).

2.6 Cutting Tool

The factors in machining operation are the selection of cutting tool for the particular application. The cutting edge is grounded, and it can be modified to fit a specific machining technique if necessary. Manufacturing of the new materials for structural work piece is directly related to the need of new material for cutting tools such as to be able make the shape of work piece with high accuracy and high quality of surface without excessive tool wear. Cutting tool position is one of the most crucial factors influencing dimensional and geometric tolerances, and cutting tool deflection can have a negative impact on tolerances. Ensuring that the workpiece has the appropriate dimensions and geometric quality is crucial during turning. Deflection of the cutting tool during the turning process is crucial, particularly for geometric tolerances like roundness and cylindricality (Lin et al., 2021). As seen in Fig. 2.3, schematic illustration of the setup in the turning center machine, where v_c, f_n, a_p, and k_r represent the cutting speed, feed rate, depth of cut and entering angle, respectively.

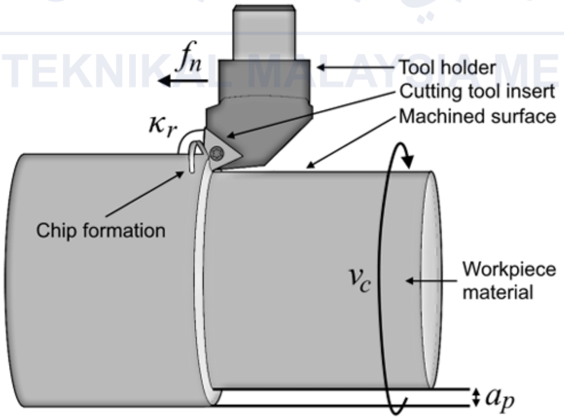


Figure 2.3: schematic illustration of the setup in the turning center machine, where v_c, f_n, a_p, and k_r represent the cutting speed, feed rate, depth of cut and entering angle, respectively.

2.6.1 Geometry Cutting Tool

Tool geometry are important role in determining the machining performance, which include cutting forces, tool wear, surface finish, chip formation, and chip breaking (Khan T., A., et al., 2013). Recent research has shown how crucial it is to optimise tool shape in order to maximise tool life in machining, which has significant financial implications. The important effect that tool geometry, including the angle of inclination, has on machining efficiency. The tool inclination angle, which has been incorporated into several mathematical models of chip flow, is a significant determinant of the direction of chip flow during milling. When inserting the cutting tool's edge into a spinning work piece, certain angles are crucial. These angles consist of the lead or entry angle, tool nose radius, rake angle, effective rake angle, and angle of inclination.

Asad M., Naeem A. A., el al. (2017) found that sustainable production will get when make a new design of an eco-friendly turning insert through machining process has been proposed. There have some direct and indirect advantage to proposed the newly design of the insert are:

- Less side burr formation;
- Fewer resources requirement for deburring process to get final product (including machines, man, money and time);
- Longer cutting insert life (with fewer chances of chipping and fracture);
- Lesser emission of CO2 (Indirect benefit: less energy is required to get final finished product and less energy is necessary with longer tool life).

2.6.1.1 Rhombic with 2 Point Angle of 80˚

In turning on AISI 1040 steel, Neseli S. et al. (2011) report that they used different-geometries AL2O3 coated tool inserts (CNMG 120404 BF, CNMG 120408 BF, and CNMG 120412 BF) for finishing operations in order to determine the impact of tool geometry on the surface finish attained. They have found that the rake angle has the greatest impact on lowering surface roughness, and that the impact of the approach angle and tool nose radius increases as surface roughness increases. A large point angle is powerful, but due to the fact it has a large cutting edge engaged in the cut, it requires more machine power and vibrates more easily. The point angle of 80˚, rhombic shaped insert is frequently used as it is an effective compromise and really suitable for a variety of situations and operations.

Figure 2.4: Insert Rhombic with 2 Point Angle of 80˚

2.6.1.2 Rhombic with 2 Point Angle of 35˚

The best tool inserts for better surface roughness in turning of alloy steel is DNMG 150412 PF compare to TNMG 220408 PF and SCMT 09T304 PF which is same ranking as Analytical Hierarchy Process (AHP) method Patel N. el al. (2012). Based on research they are proposed that evaluates and ranks of tool insert for best surface finish in turning process.

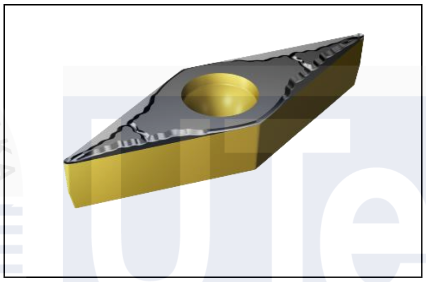


Figure 2.5: Insert Rhombic with 2 Point Angle of 35˚

2.6.1.3 Trigon with 3 Point Angle of 80˚

Applying the maximum point angle achievable will provide insert strength and reliability. However, this requires to be balanced with the variety of cuts that must be made. In this section the magnitude of the point angle determines the tool's adaptability through the degree of tool access (compare a square insert to a 35-degree point angle insert.)

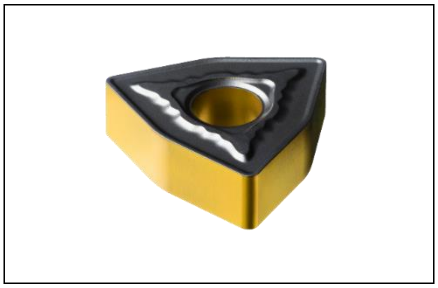


Figure 2.6: Insert Trigon with 3 Point Angle of 80˚

2.6.2 Insert Uncoated Tungsten Carbide

Nitrides, borides, silicate, and hard carbide particles combine to form a new substance called carbide tools. To attach the chemical together, a binder like cobalt is utilised. The impact strength and high temperature resistance of carbide tools, together with their hardness and grain size limitations, are some of the factors that affect their efficiency. Hamadi et al. (2022) found that using uncoated carbide during turning of AISI 4340 steel material found that abrasion will be the main wear mechanism and observation of phenomena of catastrophic failure.

Tungsten carbide is extensively used in worn components, metal cutting tools, and dies of many kinds. Tungsten, tantalum, titanium, or various combinations of these elements are often cemented or sintered in a matrix binder like cobalt to form tungsten carbide. These carbides performed better when used to machine non-ferrous, non-metallic, and cast materials, but not well enough when used to machine steel. A number of modifications to the original patents have resulted in improvements to the hard carbide. These modifications mostly concern the substitution of other carbides, primarily tantalum or titanium carbide, for all or part of the tungsten carbide. According to H. Shao et al. (2013) found that the majority of the time, sintered tungsten carbide tools are used for limited stiffness when cutting hard-to-cut materials.

2.7 Cutting Tool Wear

Considering the increasing quality of machined material, there is a growing need for the cutting tools to be of high quality. The factors that are affect to the accuracy processing is the cutting tool wear. There has different method but in this project the researcher is use Taguchi because the methods have greatly facilitated of cutting tool wear (Murat S. el al., 2014). One of the most detrimental phenomena in the cutting process is cutting tool wear, which develops under challenging circumstances and varies depending on the manufacturing method and different cutting parameters.

Zeqiri F. and Fejzaj B. (2022) claimed that when the cutting depth are increase, the amount of the cutting tool wear also increases and that the depth of cut has a greater impact in tool wear. The researcher is use cutting tool CNMG 120408 NN in turning of the Inconel 625 and obtained mathematical models and form the calculation realized with Minitab 2017. Cutting tools go through a very rough rubbing procedure. During the turning process, there is significant stress and temperature and metal-to-metal contact between the chip and the work piece. The significant stress and temperature gradients that are present close to the tool's surface make the issue worse.

2.7.1 Flank Wear

When a tool's portion comes into contact with a finished part's erosion, flank wear happens. Wear on the tool's flanks was created by the friction force between its surfaces and the work piece's surface. Tool fragments attach to the work piece because to interference between the tool's flank face and the work piece's machine surface, and they periodically shear off. Since the flanks wear principle increases cutting forces and causes other issues, it must be measured. Wearing is the primary factor that has a significant impact on the carbide tool's life duration. Without significantly slowing down the pace of material removal, a number of steps must be made to decrease the flank wear's increase rate. According to the study, the wear on the flanks typically increases linearly with increases in feed rate, depth of cut, and cutting speed. A statistical model was developed to illustrate the variation between the experiment's expected and actual flank wear. The results showed that, with a 96.33% to 98.92% confidence level, the predicted flank wear value was approximately closer to the observed value (Kumar R., et al. 2022).

2.7.2 Crater Wear

The cratering phenomenon happens at the tool-chip contact area, where the high loads and high temperature from the cutting process cause the cutting tool to come into touch with the moving chip's friction force. While the work piece material's thermal characteristics mostly influenced the diffusion wear, the mechanical characteristics of the work piece material, such as yield stress and hardness, affected the abrasive wear. It has been found that crater wear changes as cutting speed increases from moderate, conventional cutting speeds to high speed machining conditions has not been investigated before.

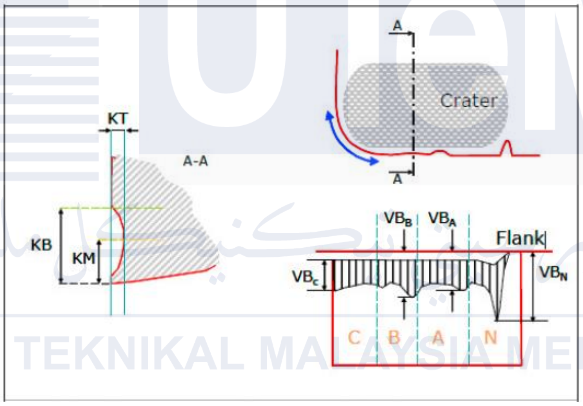


Figure 2.7: Illustration of tool wear and associated measurements as defined by the standard ISO 3685

The width and depth of the flank worn land crater rise in direct proportion to the cutting speed increase. Both characteristics increase by an average of two times over the tool life when the cutting speed is increased from 150 m/min to 300 m/min. Wear rates rise as well, although more dramatically. There is a factor of seven in the rate of crater wear development (Gordon S. et al. 2019).

2.8 Tool Life Criteria

According to Qehaja N. et al. (2017), the amount of real cutting time that a tool has before it becomes unusable is known as its tool life in turning. Tool life can be defined in a number of ways; typically, the end of a tool's life is measured by setting a maximum allowable wear limit. The amount of usable time that has passed before the cutting tool has ceased to generate workpieces that are satisfactory is known as tool life Axinte D. A. et al. (2001). Reducing manufacturing costs and enhancing the quality of machined components need the forecast and control of tool life for an integrated tool selection system.

Joginder Singh et al. (1983) found that the easiest criterion to apply for evaluating tool life is the maximum machining ratio, which is based on the combined wear of the flank, crater, chip notching, and primary and secondary grooving. Tool geometry, process parameters, and the materials of the tool and workpiece all affect how quickly a tool wears out. Reduce the cutting speed in order to maintain a steady tool life, and the tool life can be calculated using the following formula:

$$T = \frac{K}{C^n}$$

where:

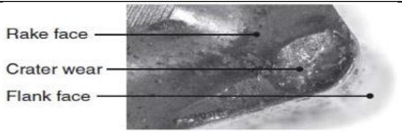
- T is the tool life
- K is a constant that depends on the tool material and workpiece material
- C is the cutting speed
- n is an exponent that depends on the type of wear criterion used

2.8.1 Tool Life Modes

The many mechanisms of tool wear and failure during the cutting process are referred to as tool life modes. The amount of real cutting time that a tool has before it becomes unusable is known as its tool life. According to Safavi M. et al. (2020) abrasion, diffusion, and adhesion mechanisms are the primary wear modes in turning Ti-MMCs. Tool wear morphology and cutting force profile change with lubrication mode and cutting speed.

Tool life in turning titanium alloys is mainly affected by chip adhesion due to high cutting heat, and enhancing cutting speed control is crucial for improved process accuracy and tool life You S. et al (2019). It is imperative to comprehend and keep an eye on different forms of tool wear in order to maximise machining efficiency. In order to evaluate and forecast tool wear and enable prompt tool replacements and maintenance, methods like tool wear analysis, tool life testing, and condition monitoring can be used. The tool life modes in turning operations are also greatly influenced by variables such as cutting speeds, feed rates, tool material, and workpiece material. Table 2.1 are shown type of wear mechanism.

Table 2.1: Type of wear mechanism

Wear in Cutting Tool	Wear Mechanism
	Flank Wear
	Crater wear
	Thermal Cracking
	Flank Wear and build-up edge (BUE)

2.9 Design of Experiment

The design of experiment (DOE) is significant point as structured and as organize method for investigates the connection between factors affecting process and the result of the experiment of the experiment process. DOE will be illustrated as a way and application to plan and run repeated of experiments. According to Tye H. et al. (2004) High-throughput automation systems and design of experiments (DoE) techniques can greatly boost drug development productivity. DOE is a powerful statistical methodology used to understand how changing input variables (factors) affects a desired output (response). It's similar to carrying out a controlled study to determine the causal links inside a system or process. DOE assists in identifying the factors that significantly affect the reaction, removing those that are not relevant and concentrating efforts on those that are. It also helps to minimise unintended fluctuations in the response, resulting in a more consistent and predictable outcome. Senthilkumar N. et al. (2014)

found that when turning AISI 1045 steel, the response surface methodology (RSM) and firefly algorithm optimise the machining parameters to reduce flank wear and increase the rate of material removal.

Montgomery, (2020) stated that the method used to set up the experiment is called DOE. Mathematical technique, true as a consequence, and objective inference can be used to evaluate relevant results. A collection of computational and mathematical methods known as experimental design techniques are helpful for problem-solving and issue-modelling.

2.9.1 DOE Overview

The methodical and controlled process of organising, carrying out, and evaluating experiments is known as Design of Experiments (DOE). It is applied to lower expenses, increase process efficiency, and enhance product quality. In industrial processes like turning, where it can help identify the elements influencing the process and define the ideal conditions for obtaining the intended outcomes, DOE is very helpful. Model-based experiment design (DOE), which has applications in a variety of domains including chemical kinetics and biological modelling, is a crucial instrument for the quick construction and validation of mathematical models in process engineering Franceschini G. et al. (2008).

DOE can be used to optimise surface roughness, tool life, and the effects of outside variables, among other components of the turning process. Manufacturers can increase process performance and product quality by employing DOE to analyse the factors influencing the turning process in a methodical and effective manner.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter describes in precisely the method applied, flowchart, parameter that used and the equipment involved in the experiment was conducted to achieve the stated objectives of the study undertaken. In this chapter, the approaches utilized in this study will be thoroughly detailed, along with the PSM 1 and PSM 2 process flows. The first step of the chapter was gathering data from various material and moved on to the examination of the data. Workpiece material that used in this project is titanium alloy with 6% aluminum and 4% vanadium Extra Low Interstitial (Ti-6Al-4V ELI) while experimental wheel was done using a lathe machine numerically controlled (CNC) axes designer HAAS CNC in dry condition. This study used a variety of cutting speeds, feed rates, and cut depths to conduct studies on titanium alloy (Ti-6Al-4V ELI) in dry condition. 3 different geometries inserts were used to manufacture the workpiece such as rhombic with 2-point angle of 80˚, rhombic with 2-point angle of 35˚ and Trigon with 3-point angle of 80˚. The study looked at wear mechanism, tool life, and pattern of flank wear as output characteristics.

3.2 Experimental Procedures

Interrupted turning cuts were carried out at dry condition with difference geometries of cutting tool inserts. The measured parameter to represent the progress of wear was flank wear of tool, Vb. The cutting test run was periodically interrupted for each 20 mm of length and the insert was taken out for measure tool wear progression by tool microscope. The cutting speed is set at 120, 170, and 220 m/min, feed rate is set at 0.1, and 0.2 mm/rev and depth of cut are set at 0.5 mm.

The experiment is repeated with difference geometries cutting tool inserts, new workpiece. The obtained data were analysed in order to investigate the performance of tool life value on difference geometries carbide cutting tools and tool wear pattern on the cutting tool during turning titanium alloy TI-6Al-4V ELI under dry condition.

Figure 3.1 represents the overall project procedures flow chart. Using an uncoated carbide tool and Ti-6Al-4V ELI materials, the initial stage of machining is performed. Then, applying recommendations from specifications and literature, the cutting parameters for the experiment were found to be suitable for the Ti-6Al-4V ELI turning process. The experimental work design was used to replicate the turning process from the previous experiment in order to find the optimal cutting parameter and tool life.

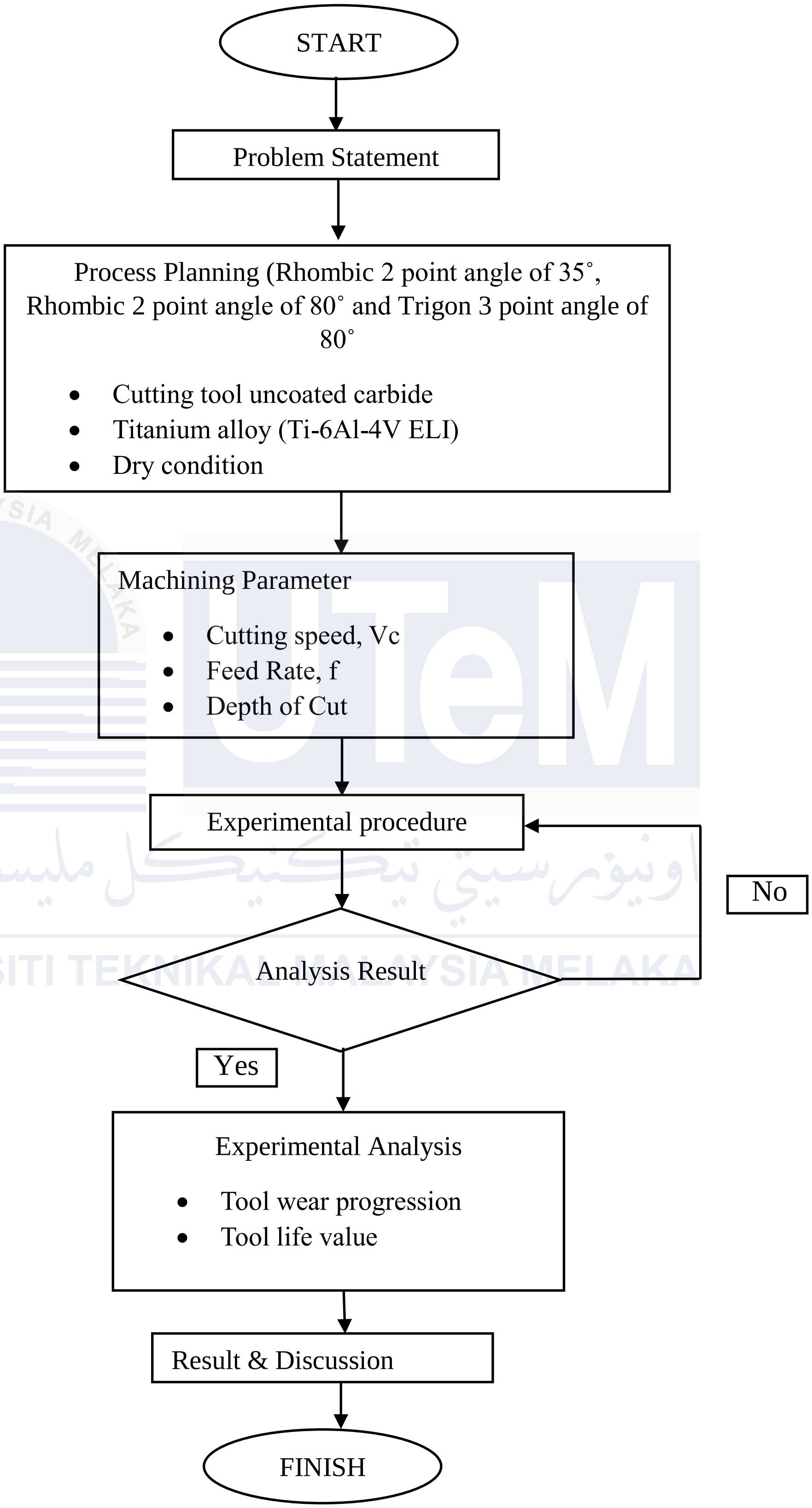


Figure 3.1: Flowchart of the project

3.3 Data Collection

It has been determined to use the data acquired during the data collection process to realise the methodology employed in this project. An essential component of statistical analysis is data collecting. Several methods of information gathering were employed in this project. Primary sources and secondary sources were used to categorized the techniques.

3.3.1 Primary Source

Primary sources, sometimes referred to as real-time sources, are the authentic and first-hand information data that the researcher has developed. Primary sources are the information source used in this project. There are two categories for primary sources: quantitative and qualitative data.

To put it simply, qualitative data indicates that the information gathered does not take the shape of a numerical representation of the data. The observation technique was employed in this study to acquire qualitative data. Information that has been measured and quantified is referred to as "quantitative data". Analysis and comparison will be used to collect data for this project.

3.3.1.1 Observation

Observation is a method of gathering data that involves observing characteristics and processes in everyday situations. In this project, observation was done to determine the purpose, scope, and description of the issue. Critical evaluations and findings from earlier studies will also be utilized to bolster the conclusion.

3.3.2 Secondary Source

Data were collected and analysed with the use of secondary sources, and the results were connected to factual and theoretical information obtained from other sources. In spite of this, the primary data was examined and evaluated alongside the information obtained from secondary sources. Utilising various carbide tool geometries, this source was employed in the investigation and analysis of cutting tool performance (tool life and wear pattern) in the turning of titanium alloy Ti-6Al-4V ELI. In addition, the information acquired was used to produce the literature review, which improved the coherence and clarity of the problem's explanation. In this study, secondary sources included papers and journals as well as websites.

3.3.2.1 Journal/ Article

For the purpose of this research, journals and articles are being used as sources to obtain information and data for the literature review. Because of copyright concerns, certain periodicals and articles are not available. International universities provide some of the sources. Since the information is virtually direct to the project's title, the data from this source are extremely limited.

3.3.2.2 Internet

The internet provides a wide and ever-changing panorama of information, making it a veritable gold mine of secondary sources for research. It offers a wide range of viewpoints and ideas on every imaginable issue, from legitimate news sources and industry reports to academic articles and research databases. The instantaneous nature and ease of access to internet resources facilitate swift research and discovery of pertinent material, while sophisticated search engines and filtering tools aid in navigating the deluge of information. However, as the internet also has biased and unreliable content, critical analysis and source verification are essential. Through the use of credible organisations, well-established academic venues, and a healthy dose of scepticism, researchers can effectively leverage the internet's immense potential to enhance and reinforce their research.

3.4 Experimental Equipment

Most scientific research begins with an experimental procedure. Through a series of painstakingly prepared steps, it is the comprehensive roadmap that leads researchers from their initial query to a definitive solution. Consider it as a methodical approach to discovering scientific truth, where each phase guarantees accuracy and consistency for dependable outcomes.

In general, the process begins with a brief description of the hypothesis—a provisional account for the phenomenon that has been seen. The experimental design is the next step, which entails defining the variables (a.k.a. components that are manipulable or measurable) and the means by which they will be controlled. This entails determining the dependent variable, which is the one that varies in response to the manipulation, and the independent variable, which is the one being manipulated. With the exception of the independent variable's manipulation, the control group adds an essential layer of comparison that enables researchers to separate the independent variable's impact. In order to ensure impartial and correct recording of observations and measurements, the protocol also specifies the data gathering methods.

3.4.1 CNC Lathe Machine

A three-axis CNC lathe was used to perform the tasks. Figure 3.2 shows the apparatus used in the previous experiment. The features and capabilities of this machine are detailed in Table 3.1 Cylindrical workpieces are frequently machined on turning machines, and a cutting tool is used to reduce the diameter of the workpiece.

Figure 3.2: CNC Lathe Machine

Table 3.1: Features and capabilities of the machine

Capabilities of Machine	Specification
Size of Chuck	210 mm
Maximum of Cutting Diameter	381 mm
Maximum of Cutting Length	533 mm
Bar Capacity	52 mm
X-Axis	237 mm
Y-Axis	536 mm
Rapids on X	24.0 m/min
Rapids on Z	24.0 m/min
Maximum of Thrust X	18238 N
Maximum of Thrust Z	22686 N
Maximum of Rating	14.9 kW
Maximum of Speed	4000 rpm
Maximum of Torque	203 Nm @ 500 rpm
Nose of Spindle	A2-6
Bore of Spindle	88.9 mm
Number of Tools	12 Stations
Air Required	113 L/min, 6.9 bar
Capacity of Coolant	208 L

3.4.2 Dry Condition

Dry machining is not a universally applicable solution. Care must be taken while choosing the material because some metals produce too much heat in the absence of coolant, which can damage and wear down tools. To endure the increased friction, specific instruments with heat-resistant coatings are frequently needed.

With its advantages for the environment, increased safety, and possible productivity increases, dry machining is a promising alternative in the field of metalworking. Its benefits cannot be understated, making it a feasible solution for some applications within the constantly changing manufacturing landscape, even if it requires careful material selection and specialised tools.

3.4.3 Workpiece Material

The titanium alloy used in the workpiece of the earlier research experiment contained 6% aluminium and 4% vanadium. It was also called Extra Low Interstitial Ti-6Al-4V ELI, and it had a cylindrical shape. The mechanical properties and chemical composition of Ti-6Al-4V ELI are displayed in table 3.2 and table 3.3 Figure 3.3 is show workpiece of Ti-6Al-4V ELI.

Figures 3.3: Workpiece of Ti-6Al-4V ELI

Table 3.2: Mechanical Properties of Ti-6Al-4V ELI

Mechanical Properties	**Value**
Density	4428.78 kg/m^3
Tensile Fatigue	900 MPa
Ultimate Tensile Strength	970 MPa
Thermal Conductivity at 20 ˚C	6.6 W/ m/ K
Specific heat at 20 ˚C	0.580 J/ gK
Elongation	13%
Hardness	241 HB
Tensile Strength at 400 ˚C	550 MPa
Elastic Modulus	107 – 122 GPa
Shear Modulus	41 – 45 GPa

Table 3.3: Chemical Composition of Ti-6Al-4V ELI

Element	C	Si	Fe	Ti	Al	N	V	S	O	H	Y
Wt%	0.11	<0.03	0.18	Bal.	6.1	0.007	4.0	<0.003	0.11	0.0031	<0.005

3.4.4 Cutting Tool

When it comes to turning, the cutting tool is ruler. It is the silent maestro who turns raw materials into exact, completed pieces; the sculptor of metal; the shape-magician. In contrast to conventional machining tools, the turning tool glides along the spinning surface of the workpiece, dancing with it to eliminate undesired material and reveal the desired shape.

There are several guises for this modest hero, each one designed for particular materials and duties. The single-point cutting tool is the most popular kind; it is a thin bar with a sharp tip that glides over metal, removing layers with each pass. Depending on the workpiece's abrasiveness and hardness, these tools can be constructed from a variety of materials, including carbide, high-speed steel, and even diamond. In this research, 3 difference geometries of uncoated carbide insert with the ISO code CNGG 120408-SGF H13A, WNMG 080408E-4T and VBMT 160404 ET9025 was utilised for the test.

3.4.4.1 Rhombic shape with 2-point angle 80°

The cutting insert for the turning operation is shown in Figure 3.4. The operation type of the insert is finishing with 2 insert mounting style code.

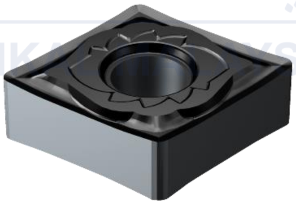


Figure 3.4: CNGG 120408-SGF H13A

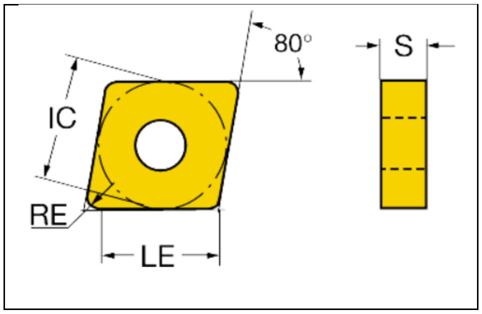


Figure 3.5: Technical Illustrations

Table 3.4: Geometric Dimensions of the carbide tool CNGG 120408-SGF H13A

Dimensions	Size
Inscribed Circle Diameter, *i*C	12.7 mm
Insert thickness, s	4.76 mm
Corner radius, r_ε	0.80 mm
Cutting edge effective length, *l*	8.5 mm

3.4.4.2 Rhombic shape with 2-point angle 35°

The cutting insert for the turning operation is shown in Figure 3.6. The operation type of the insert is roughing with 2 insert mounting style code.

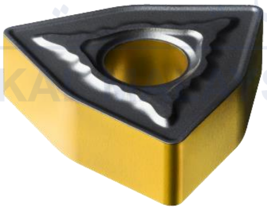


Figure 3.6: WNMG 080408E-4T

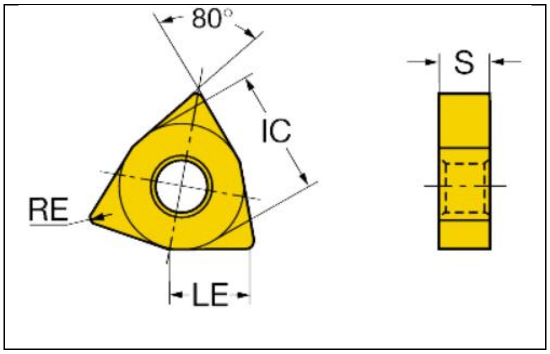


Figure 3.7: Technical Illustrations

Table 3.5: Geometric dimensions of the carbide tool WNMG 080408E-4T

Dimensions	**Size**
Inscribed Circle Diameter, *i*C	12.7 mm
Insert thickness, s	4.76 mm
Corner radius, r_{ε}	0.80 mm
Cutting edge effective length, *l*	7.89 mm

3.4.4.3 Trigon shape with 3-point angle 80°

The cutting insert for the turning operation is shown in Figure 3.8. The operation type of the insert is medium with 3 insert mounting style code.

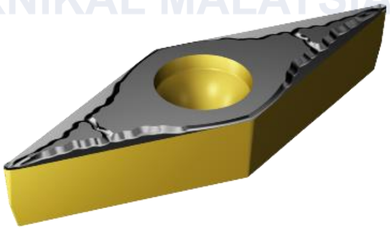


Figure 3.8: VBMT 160404 ET9025

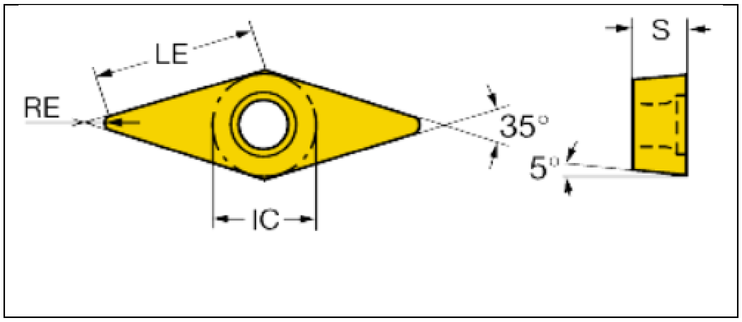


Figure 3.9: Technical Illustration

Table 3.6: Geometric dimensions of the carbide tool VBMT 160404 ET9025

Dimensions	**Size**
Inscribed Circle Diameter, *i*C	9.53 mm
Insert thickness, s	4.76 mm
Corner radius, r_ε	0.40 mm
Cutting edge effective length, *l*	16.20 mm

3.4.5 Tool Holder

In turning machining, the tool holder is essential because it serves as a link between the machine tool and the cutting tool. It's the robust arm that steadily holds onto the fragile dancer—the cutting tool—and precisely directs its movements. Selecting the appropriate tool holder is contingent upon several elements, such as the nature of the machine tool, the composition of the workpiece, and the intended machining processes. Each holder must provide the necessary rigidity and stability to withstand the cutting forces while guaranteeing exact alignment and movement of the cutting tool. The tool holder's contribution to total machining efficiency extends beyond its functional duty. It minimizes downtime and increases production by speeding up setup times and enabling accurate tool positioning. Figure 3.10 show the 3 different of tool holder used for this test.

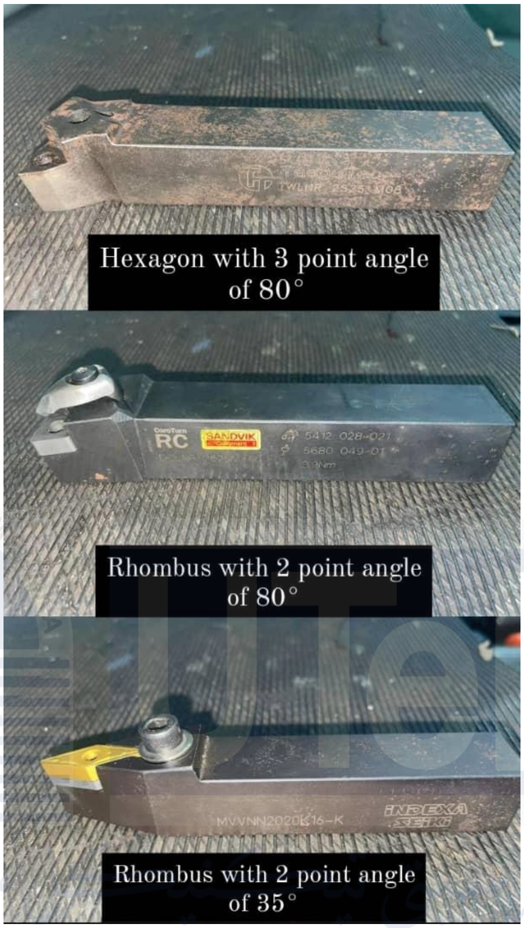


Figure 3.10: Tool Holder

3.4.6 Toolmaker microscope

To monitor and quantify the cutting tool's wear evolution in this study, a toolmaker's microscope is needed. This instrument can be used to identify the flank wear and crater wear. This equipment where represented in Figure 3.11 and its specification in Table 3.7. There are three axes in this equipment which X, Y, and Z axes.

Figure 3.11: The Mitutoyo TM Series

Table 3.7: Specification of Mitutoyo TM Series

Equipment Capabilities	**Specifications**
Optical tube	Monocular type (Vertical tilt angle: 60˚)
Observation image	Erect
Eyepiece protractor	Resolution (Graduation): 1˚ Rotation angle: 360˚ Resolution (angle): 6˚ Adjustable zero point
Eyepiece	Standard accessory: 15X (field number: 13) Options: 10X, 20X
Objective lens	Standard accessory: 2X, Options: 5X, 10X

3.5 Design Procedures

This study objective to investigate the performance of tool life value on difference geometries carbide cutting tools and to analyze tool failure mode and tool wear pattern on the cutting tool during turning titanium alloy Ti-6Al-4V ELI under dry condition. Multiple preparatory experiments must be conducted before to the experiment to ensure that the goal of the experiment is met and the experiment proceeds without a hitch. The CNC lathe machine, optical microscope, and other equipment are the primary machines and equipment that need testing. Schedules for documenting flank wear and tool life according to times are also required, in addition to the need for CNC programming.

Cutting speed (Vc) in this experiment was chosen based on the high cutting speed average. According to previous research, the majority of tungsten carbide tools are used at 100–200 m/min cutting speeds. This explains why a cutting speed of at least 100 m/min is chosen. Due to its extensive use in hard turning processes in industry, tungsten carbide tools were also chosen. The optical microscope is used to measure the maximum (Vb max) or average (Vb avg) amount of flank wear. Each 20 mm cutting length has response data recorded, and the experiment will conclude when the end tool life is reached.

Table 3.8: Experiment running schedule that designed by using experimental work design

Run	Cutting Speed, (m/min)	Feed Rate, (mm/rev)	Depth of Cut, (mm)
1	90	0.1	0.4
2	90	0.2	
3	120	0.1	
4	120	0.2	
5	150	0.1	
6	150	0.2	

CHAPTER 4

RESULT AND ANALYSIS

4.1 Overview

This chapter presents all the results and discussion of the results of the tests that have been carried out covering the observations that occur on tool life value and tool wear progression on 3 difference geometries uncoated carbide that will be explained in more detail. The wear mechanism of cutting tool, tool life and tool failure mode will also be discussed in detail. The comparison of the tool wear progression and tool life for 3 difference geometries of carbide tool.

4.2 Tool Life Analysis by Experimental Work Design

Tool life was strongly influenced by temperature generated and the force utilised under condition of the turning process. Beyond that, the changes in cutting speeds, feed rate and depth of cut will have a direct impact on the cutting force and temperature that are produce at or near the cutting edge of the insert carbide.

4.2.1 Rhombic with 2-Point Angle of 80˚

The sort of uncoated carbide used in this experiment was utilised to investigate the performance of the tool life during dry cutting. To observe the performance of the combination of cutting speed and feed rate with constant depth of cut, 80˚ rhombic shape of carbide (CNGG 120408-SGF H13A) is used.

Table 4.1 show the tool life in minutes 80˚ rhombic shape uncoated carbide used during the final run of titanium alloys Ti-6Al-4V ELI in dry cutting conditions.

Table 4.1: Tool life value of 80˚ rhombic

Run	Feed rate (mm/rev)	Speed (m/min)	Tool life (min)
1	0.1	150	2.03
2	0.2	150	1.08
3	0.1	120	2.67
4	0.2	120	1.34
5	0.1	90	3.41
6	0.2	90	1.7

By referring to Table, the maximum tool life is 3.41 minutes in cutting speed 90 m/min, feed rate 0.1 mm/rev. While the minimum tool life is 1.08 minutes in cutting speed 150 m/min, feed rate 0.2 mm/rev. Respectively in constant depth of cut in 0.4 mm. The rise in temperature and plastic deformation are responsible for the notable reduction in carbide tool life at increased feed rates (C. H. Che Haron, 2001). The tool maker microscopy images of the uncoated carbide tool indicated that the flank wear occurred in the nose region, because of the low depth of cut of 0.4 mm, which was smaller than the nose radius of 0.8 mm that was applied during the hard turning.

The optimum responses are obtained in 80˚ rhombic carbide at cutting speed 150 m/min, feed rate 0.2 mm/rev, and this give out the longest tool life of 1.08 minutes. That supported with

M. A. Sulaiman (2014) that the upper limit of cutting speed at 220 m/min for uncoated carbide tool to finish the turning titanium alloy in flooded condition have longest tool life. According to the graph, the cutting tool rapidly wear down with the increasing in cutting speed are related to the tool-life data.

4.2.2 Rhombic with 2-Point Angle of 35˚

Table 4.2: Tool life value of 35˚ rhombic

Run	Feed rate (mm/rev)	Speed (m/min)	Tool life (min)
1	0.1	150	2.05
2	0.2	150	1.01
3	0.1	120	2.59
4	0.2	120	1.29
5	0.1	90	3.48
6	0.2	90	1.73

The maximum tool life at run number 5 (Table 4.2) is 3.48 minutes at cutting speed 90 m/min, feed rate 0.1 mm/rev by according to Table 4.2. Meanwhile, the lowest tool life of 1.01 minutes was achieved at a cutting speed 150 m/min, a feed rate of 0.2 mm/rev that are remain the depth of cut for all runs in 0.4 mm. Figure 4.1 show graph responses in 35˚ rhombic at cutting speed 150 m/min and 0.2 mm/rev feed rate and that will give the better tool life of carbide tool.

Figure 4.1 shown the trend of graph for tool life with combination paratemers. For machining operations to be optimised, it is crucial to comprehend the connection between cutting speed and tool life. Rapid wear on tools might necessitate frequent tool changes, which can greatly reduce productivity and raise expenses. Manufacturers can increase overall machining efficiency and prolong tool life by opting for a different tool material that is better suited for high-temperature applications or by choosing a lower cutting speed. An increased demand for cutting tool materials with improved toughness, elevated temperature strength and chemical inertness M. Y. Noordin (2014). Regarding to the characteristics of workpiece are critical when selecting the proper geometry of the cutting tool for hard turning machining.

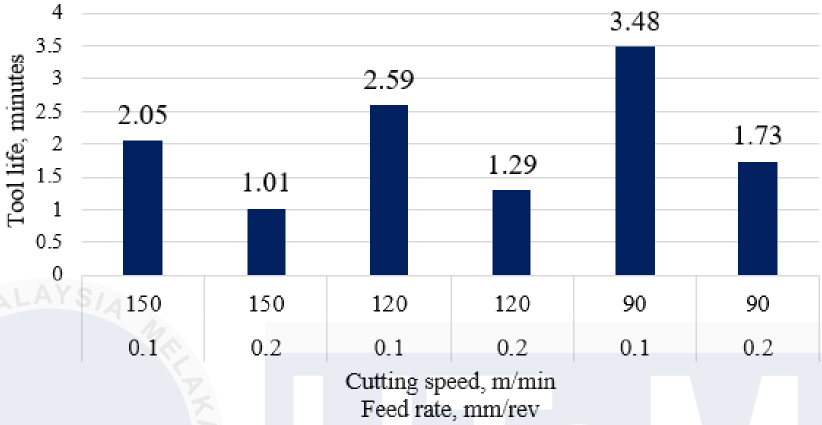


Figure 4.1: Tool life of 35˚ rhombic carbide tool.

4.2.3 Trigon with 3-Point Angle of 80˚

Table 4.3: Tool life value of 80˚ trigon

Run	Feed rate (mm/rev)	Speed (m/min)	Tool life (min)
1	0.1	150	2.02
2	0.2	150	1.05
3	0.1	120	2.64
4	0.2	120	1.32
5	0.1	90	3.55
6	0.2	90	1.77

From Table 4.3, the maximum tool life of uncoated carbide of Trigon with 3-point angle of 80˚ is 3.55 minutes that are achieved in cutting speed 90 m/min, feed rate 0.1 and constant depth of cut is 0.4 mm. Beyond the combination of higher cutting speed 150 m/min with higher feed rate are recorded as the lowest tool life 1.05 minutes. From the previous researcher state that the flank and crater wear occurred due to abrasion of hard particle on tool faces. The progression of tool wear not only affected tool life but also influenced tool fracture (A. Davoudinejad et al. 2014 and A. R. Durai et al. 2006).

Regarding to the data, higher feed rate with higher cutting speed will reduced the tool life of the uncoated carbide. Titanium element and workpiece Ti-6Al-4V ELI receive a chemical reaction that is accelerated by the high temperature created in the cutting zone during high-speed machining. According to Che Haron et al. (2007), where by turning titanium alloy workpieces may be machined effectively using uncoated carbide tool points. According to Anagonye & Stephenson et al. (2002), raising the angle point will provide more space for heat to flow into. As the included angle increase, the difference in temperature across the heat contact area becomes more even, leading to a more consistent spread of heat. Therefore, the efficiency of the insert will be enhanced by selecting the insert with the highest possible included angle for the turning process.

4.2.4 Effect of Cutting Parameter on Tool Life

In addition to the impact of the varying geometric shapes of the insert, the tool life of the cutting point tool is also influenced by the cutting speed, the rate at which material is fed into the machine, and the depth of the cut. Figure 4.2, 4.3 and 4.4 illustrate the effect of changing the value of the cutting parameter on the life of the tool point for trigon 80˚, rhombic 80˚ and rhombic 35˚ with differences to the cutting speed and feed rate in dry conditions.

Cutting parameters, feed rate and cutting speed affect the tool life result. Figure 4.2 show the tool life uncoated carbide for 3 differences geometry at constant cutting speed, 150 m/min and depth of cut, 0.4 mm. From the comparison graph, it is found that the tool life value of the tool point of each feed rate value is increased from 0.1 to 0.2 mm/rev. The rhombic shape of 35˚ angle have higher tool life in 0.2 mm/rev feed rate compare to the other geometry. This finding result agrees with previous studies reporting of Talib N. A. et al. (2010) that maximum tool life occurred with minimum speed for all feed rate value. In addition, the life value of tool point decreased for all cutting speed (150, 120 and 90 m/min) the value of the feed rate directly increases the temperature generated during the cutting of the workpiece. According to Ibrahim et al. (2009) the cutting force will also increase in parallel with increase in cutting depth and this can affect the performance of the tool point.

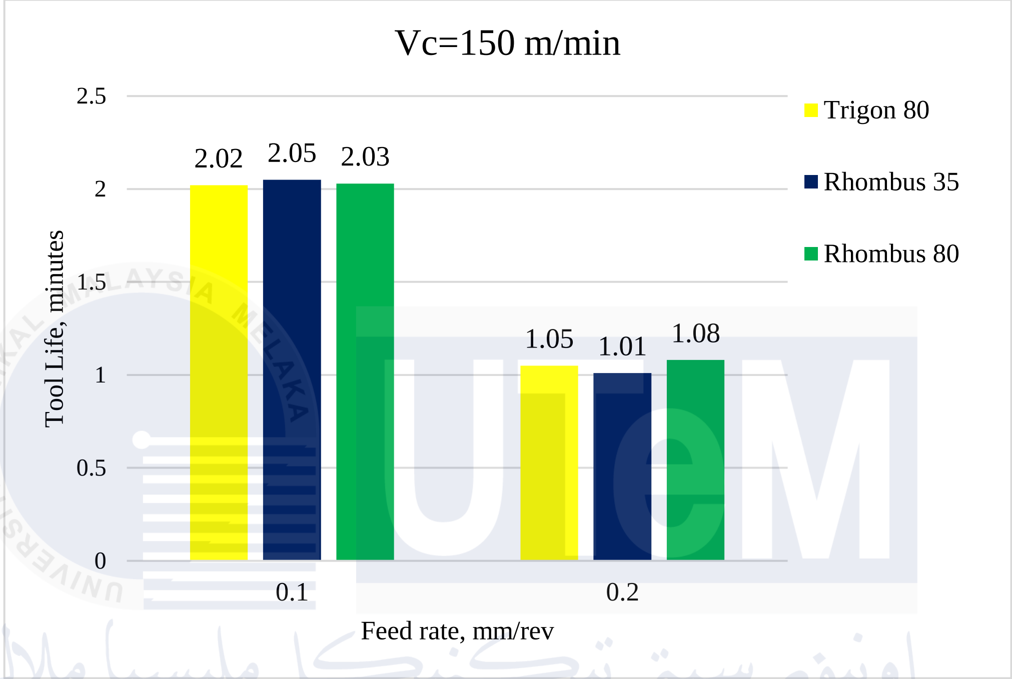


Figure 4.2: Tool life (minutes) of carbide tool at cutting speed 150 m/min

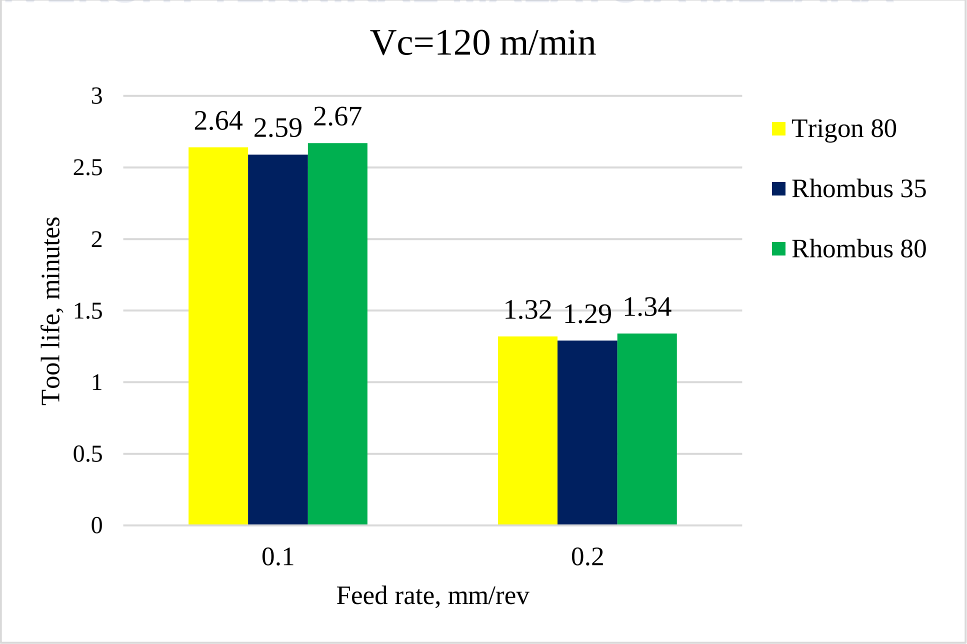


Figure 4.3: Tool life (minutes) of carbide tool at cutting speed 120 m/min

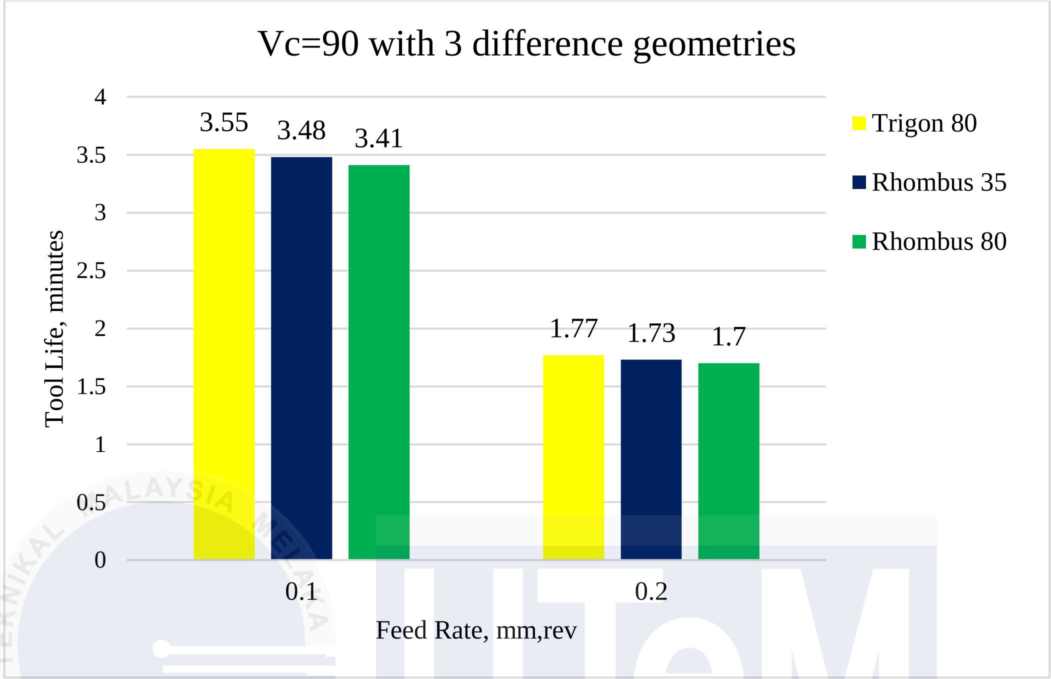


Figure 4.4: Tool life (minutes) of carbide tool at cutting speed 90 m/min

Refer to figure 4.5, the change of value in cutting speed and feed rate will extremely affect to the performance of insert carbide. There are found in figure 4.5 and 4.6, where the life value of uncoated carbide for 3 difference geometry are significantly reduced when the feed rate is increased from 0.1 to 0.2 mm/rev. For rhombic shape of 80˚ recorded was 1.7 minutes at 90 m/min cutting speed to 1.08 minutes for 150 m/min with constant feed rate 0.2 mm/rev. Similar result and pattern of graph were produced for trigon 80˚ in same feed rate 0.2 mm/rev. In all cutting conditions the chamfer edge cutting tools performed better than honed tools and longer tool life (Noordin M.Y. et al. 2014)

The increase feed rate from 0.1 to 0.2 mm/rev has caused an increase in the cutting temperature at the edge of the tool carbide and induced the occurrence of plastic deformation of the tool eye. Figure 4.6 found that for tool point trigon 80˚ for cutting speed 90 m/min recorded 3.55 minutes at a feed rate 0.1 mm/rev and the tool life value are increased to 2.02 minutes when the cutting speed are increased to 150 m/min. Aleem M. et al. (2023) claimed that at higher speeds, the achieved tool life was compromised and will got a low tool life compared to that achieved at low speed. Che Haron et al. (2016) noted that raising the cutting speed or feed rate led to a more significant rise in temperature close to the tool's cutting edge. The greater temperature, less durable both the cutting tool and material.

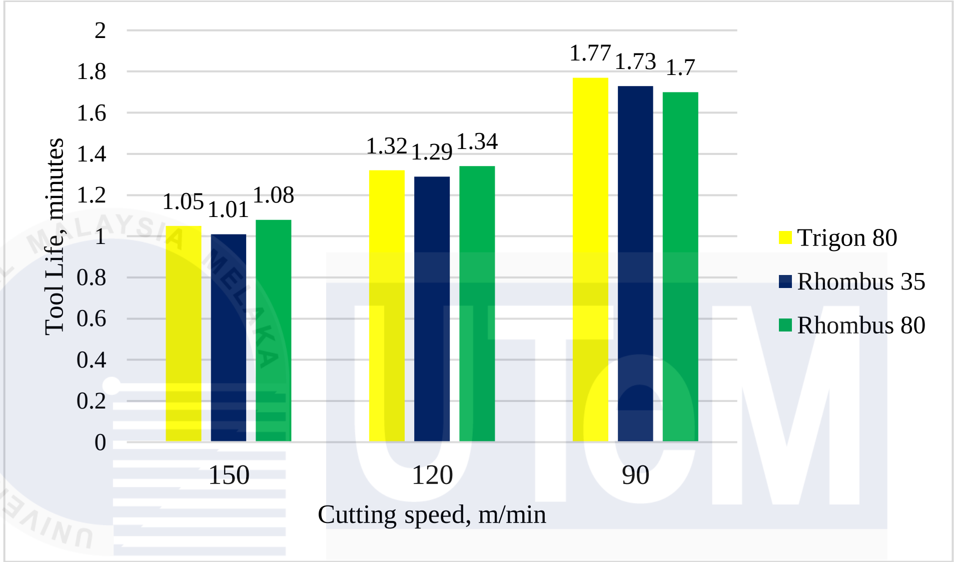


Figure 4.5: Tool life at constant feed rate (0.2 mm/rev) of cutting speed, 150,120 and 90 m/min for difference geometry carbide tool

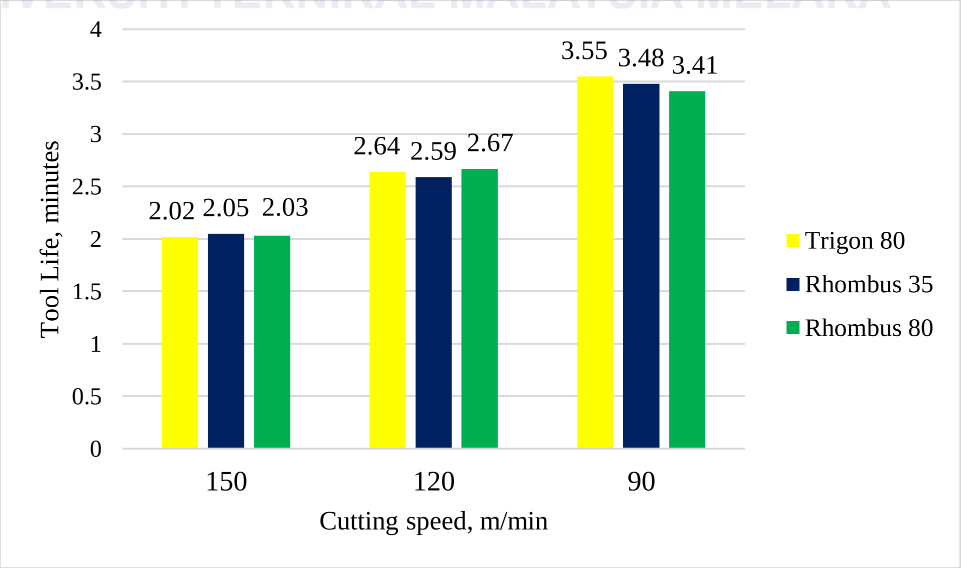


Figure 4.6: Tool life at constant feed rate (0.1 mm/rev) of cutting speed, 150,120 and 90 m/min for difference geometry carbide tool

4.3 Comparison Between 3 Type Geometry Carbide Tool

Although titanium alloys are widely recognised for their great strength and incredible corrosion resistance, it can be difficult to machine them due to these same qualities. Optimising titanium alloy turning requires a thorough analysis of tool life. This entails planning and carrying out studies to find out how different cutting parameters, such as feed rate, depth of cut, and cutting speed, impact how long a tool may be used before needing to be replaced. Relationships that forecast tool life for various machining scenarios will be established by monitoring tool wear and comparing it with these characteristics. The analysis of the results will assist producers in striking a balance between cost and productivity by optimising tool life while preserving the required dimensional accuracy and surface quality.

In the process of high-speed machining titanium alloy workpieces, the produced heat levels are extremely high at the cutting zone, which is the area between the chip and the point where the tool tip the workpiece. As a result, it's crucial to swiftly eliminate this excess heat. Failing to do so could lead to the quick deterioration of the tool tip and negatively affect the roughness of the machined surface. According to T. Ozel et al. (2008) by increasing the rake angle of the cutting tool will got the increased forces and decreased tool life. Hard turning phenomenon can be attributed to the fact that increased feed rate will directly be reduced tool life in minutes, but actually increased the amount of the material that could be removed by the tool. A more reasonable metric for tool life, as it relates directly to the number of parts that can be machined with the tool at respectively depth of cut N. A. Talib et al. (2010).

By improving the side cutting edge angle could effectively distribute the cutting heat and substantially improve the tool life in turning Inconel 718 are proved from Costes et al. (2007).

4.3.1 Comparison 3 Type Geometry Carbide Tool in 0.1 mm/rev Feed Rate

The result of the experiments that have been conducted and the tool life values of the difference geometries uncoated carbide have been obtained. Then a comparison of the tool life for the same uncoated carbide but have difference geometries carbide in dry condition can be made. The value of tool life has shown in Table 4.7.

According to figure 4.7 shown the value of tool life at 0.1 mm/rev feed rate and the 80˚ rhombic insert is highest tool life of 2.03 minutes followed with 80˚ trigon carbide at cutting speed 150 m/min and feed rate 0.1 mm/rev with constant value depth of cut (0.4 mm). Meanwhile, the maximum value of tool life at 80˚ trigon is 3.55 minutes are recorded in 90 m/min cutting speed. The increasing cutting speed of the hard turning are highly affected to tool life value of the machining. That are support with Aleem M. et al. (2023) said that at higher speeds, the achieved tool life was compromised and will got a low tool life compared to that achieved at low speed.

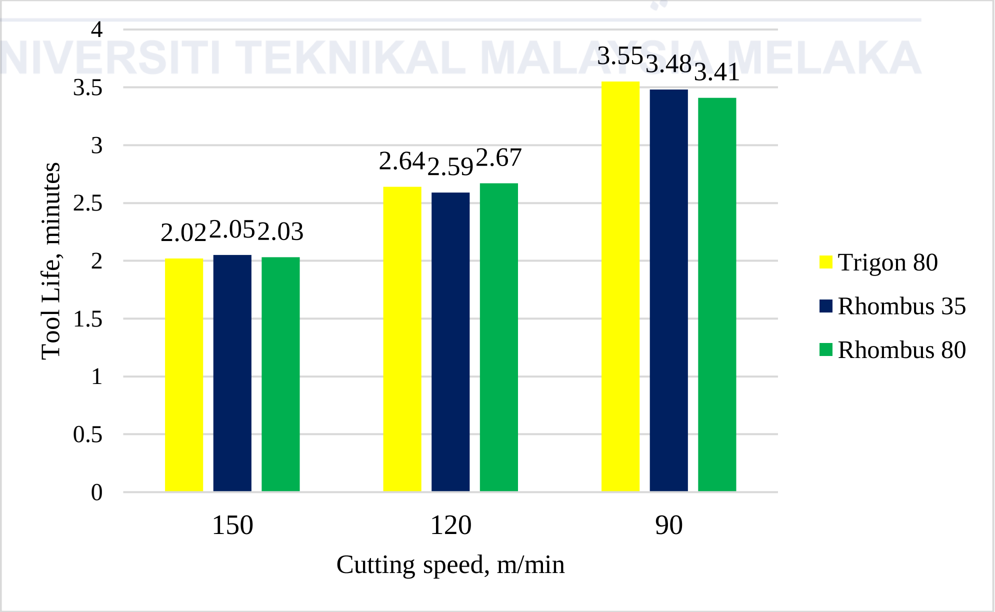


Figure 4.7: Comparison Tool life at constant feed rate (0.1 mm/rev)

4.3.2 Comparison 3 Type Geometry Carbide Tool in 0.2 mm/rev Feed Rate

The cutting zone, or the area between the tool tip and the chip, generates extremely high temperatures during high-speed machining of titanium alloy workpieces. Titanium alloys are preferred options for cutting tool materials due to their material features, which include heightened chemical reactivity and reduced heat conductivity. Because of its low heat conductivity, the temperature at a tool's cutting edge rises. A low modulus of elasticity and great strength at high temperatures are the main causes of the poor machinability of titanium alloy (Patil A. S. et al. 2024). Otherwise, it can result in rapid tool wear and damage the surface of the machined workpiece.

Based on figure 4.8, the trend of the tool life graph is quietly similar with 3 difference geometry cutting tool but the highest tool life is recorded in 1.01 minutes for 35˚ rhombic carbide while the lowest tool life is 1.08 minutes for 80˚ of rhombic at 150 m/min cutting speed. It is clear that the tool life decreases with increase cutting speed up to 90 m/min then begin to increase with increasing the feed rate respectively. Also, it is noted that maximum life occurred with minimum cutting speed followed with low value of feed rate.

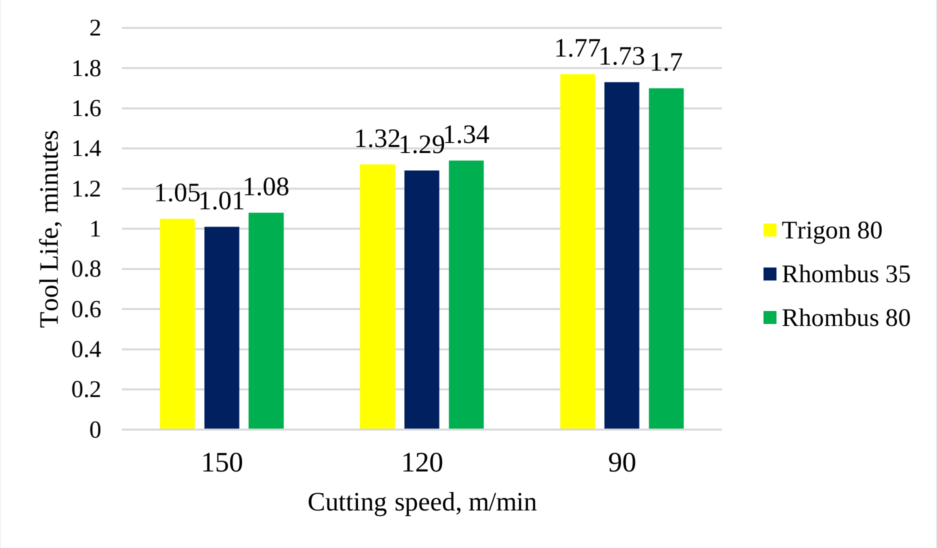


Figure 4.8: Comparison Tool life at constant feed rate (0.2 mm/rev)

4.4 Tool Failure Mode

To assess the effectiveness of the carbide point employed in this experiment performed, it must be seen in terms of resistance to the degree of wear on the tool's edge. The failure mode of a carbide tool depends on several factors and cutting parameters such as cutting speed, feed rate, cutting depth, difference tool geometry, and suitability of the workpiece with the carbide tool. The factor of wear mechanism is by abrasive, adhesive and diffusion processes (Harto B. et al. 2018).

Through the tests carried out, it was found that all types of tool points for dry condition experience nose radius wear, flank wear and crater wear. Normally nose radius wear occurs in the area near the tip of the tool as shown in Figure 4.9. Friction between the surface of the newly machined workpiece and the contact area on the edge of the tool causes wear on the face of the edge. The rib wear area is usually affected by the depth of cut. Flank wear and craters are also found and reported in most types of tool points during the process of turning titanium alloys as in previous research (Arrazola et al. 2009).

The biggest cause of uncoated carbide tool failure during dry hard turning is abrasive wear. Particles of carbide, or hard and abrasive materials found in workpieces, function like small sandpaper grains, progressively wearing down the tool's surface. The uncoated carbide's lower cutting-edge angle becomes dull and rounded due to this wear. This will cause the workpiece to have consistent surface roughness values until it become rough. When lowers surface roughness value, the surface of machined become smooth.

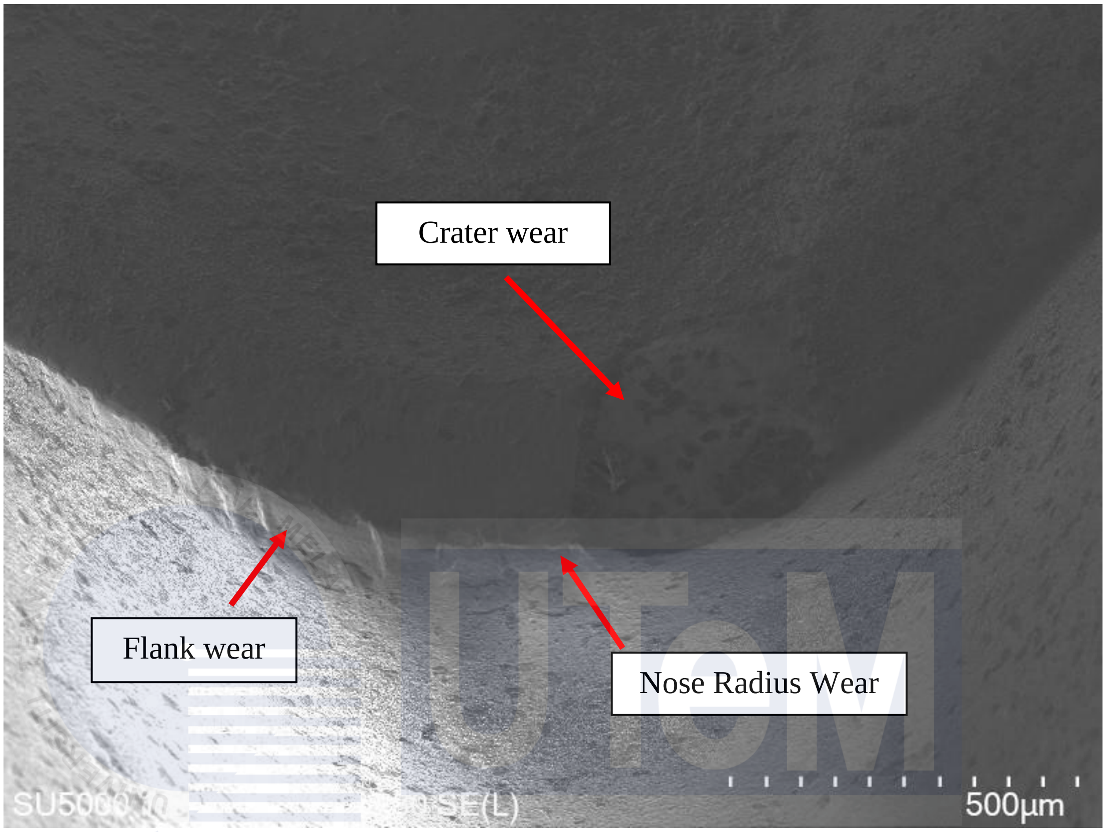


Figure 4.9: Flank wear, crater wear and notch wear that formed at 80˚ trigon uncoated carbide

The nose radius area is the encouraged wear place where the majority of cuts occur. When examined under three-axis tool maker microscopy, practically all of the tool points' edges display the same pattern. Figure 4.10 shown the mean value of wear, Vb at this stage was recorded at Vb = 0.146 mm and the time was recorded 0.4 minutes. The wear pattern at the tool insert's tip will show that the carbide tool edge insert is wearing steadily and more quickly. When the average wear value, Vb on the carbide tool edge insert reaches 0.3 mm, a big surface will eventually be created. Here, flank wear is examined and measured as it serves as a benchmark for failure and establishes the tool's lifespan.

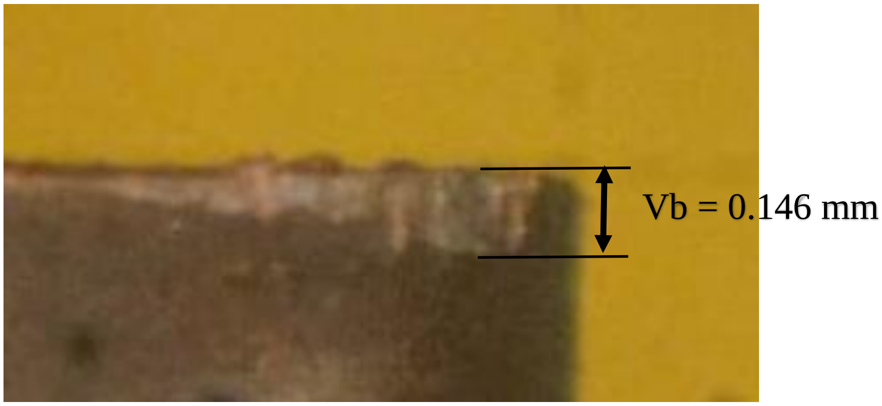


Figure 4.10: Flank wear, Vb = 0.146 mm and cutting time 0.4 minutes were recorded at cutting speed 150 m/min with 0.1 mm/rev feed rate

The preferred wear region on the flank wear, which is most affected by cutting. Almost all tool point edges exhibit the same pattern when viewed through the tool maker microscopy. Zhao J. et al. (2023) found that when turning titanium alloy at high speeds (150 m/min) as opposed to low speeds (75 m/min), carbide cutting tools break down more quickly. By using rhombic 80˚ insert are due to the fact that fast speeds put more stresses on the tool, which increases wear.

4.4.1 Wear Mechanism of Cutting Tool

It is generally accepted that various wear mechanisms can manifest themselves at the same time when workpieces with tungsten carbide tool tips are being machined. Similarly, a number of wear processes, including friction, plastic deformation, adhesion, and dissolution-diffusion, have been found in this work. High speed cutting produces temperatures over the tungsten carbide's softening point of 1100°C, which leads to this kind of mechanism.

Belloufi A. et al. (2022), temperature is one of the phenomena associated with metalworking caused the reducing the life of the cutting tool. High temperatures during metalworking are detrimental to cutting tool life, especially when working with hard materials as in hard turning. Wear is accelerated by this heat in several ways. It makes easier for atoms in the tool material to migrate around, which effectively causes them to "wash away" near the cutting edge. High or low temperatures may cause the material of the workpiece to adhere to the tool, causing friction and hastening the tool's depreciation. Ultimately, the heat may cause a weak oxide layer to build on the tool's material, increasing the likelihood of chipping and breaking. The combination of these factors is especially noticeable in hard turning because of the hard workpiece's composition. To put it briefly, heat weakens, softens, and sticks the tool, resulting in a much lower tool life.

From the previous experiment, it is also found that the difference geometries carbide tool points under dry conditions used in this machining experience the same type of wear and pattern as in Figures 4.11 is wear rate and wear mechanism of the 35˚ rhombic uncoated tool carbide under dry conditions is faster and even the wear area is larger and there is a smooth wear area on the crater wear surface. Flank wear develops when there is friction between the newly machined surface and the contact region at the cutting tool M. A. Sulaiman et al. (2014). Abrasion is the primary cause of flank wear in the majority of cutting situations, the value of flank wear is within the allowed range of 0.3 mm. This is comparable to the finding from Sahoo et al. (2013).

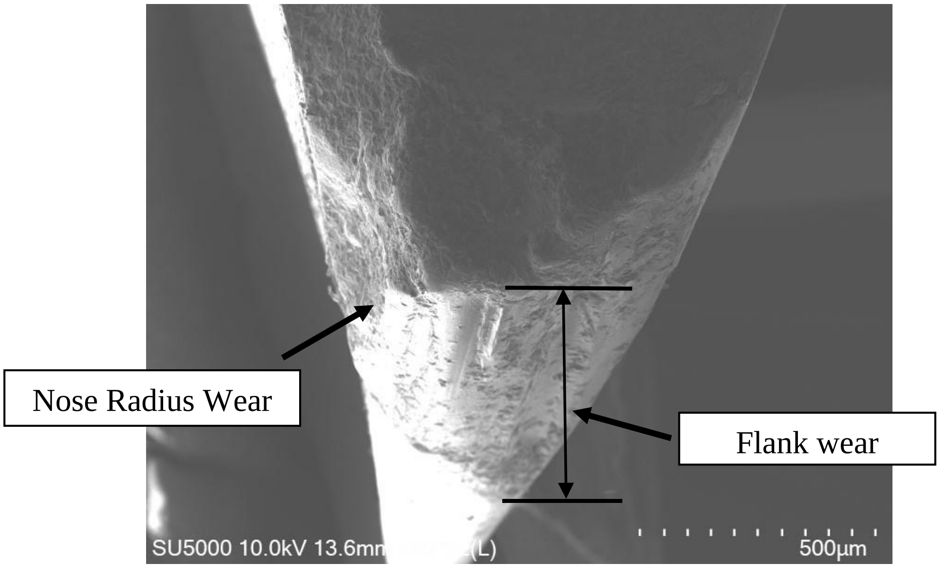


Figure 4.11: SEM image show wear at the flank face and tip of the 35˚ rhombic carbide tool under dry condition

Figure 4.12 show the tool failure mode in 80˚ rhombic carbide tool under dry condition. The lower flank wear is observer on the carbide tool for 100 mm distance of turning machining. The flank wear is observed and analysed because this type of wear is a reference for the failure and determine the life of carbide tool.

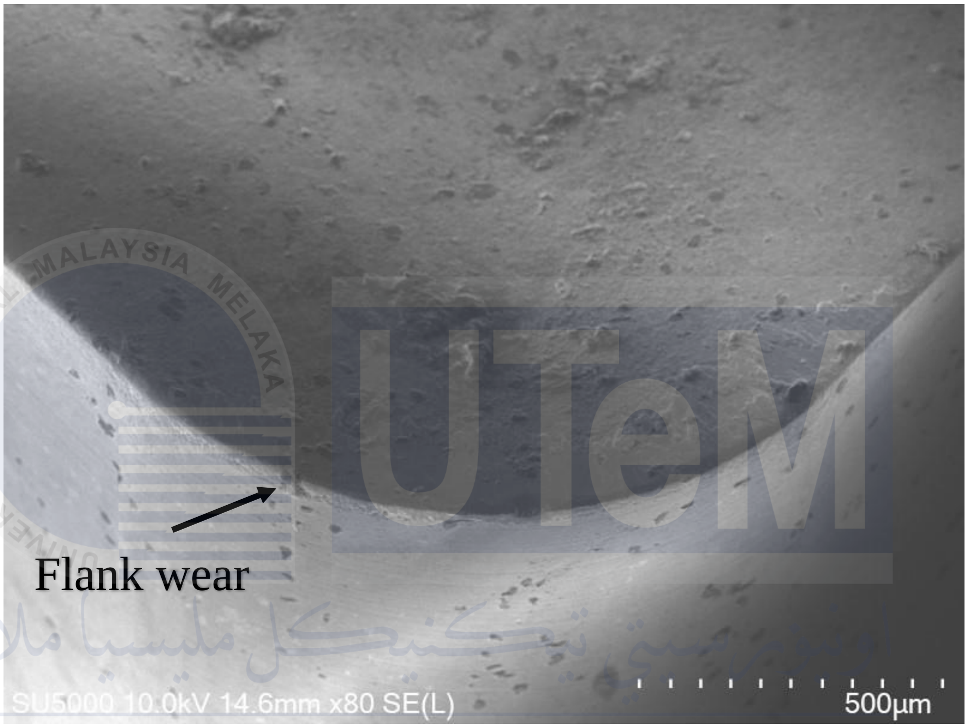


Figure 4.12: SEM image show the wear on the 80˚ rhombic carbide tool

When it comes to minimising crater wear during machining, tool geometry is essential. Larger rake angles can greatly reduce crater wear on the tool's rake face by facilitating better chip movement and lowering friction. Fatima et al. (2022) said that crater wear in a cutting process is developed by the contact and the relative sliding between chip and rake face of the tool. The region of rake face wear of crater is shown in figure 4.14. Additionally, an adequate clearance angle hinders friction between the workpiece and the flank face, which influences the advancement of crater wear indirectly. When working with hard or abrasive materials, adding chamfers to the cutting edge helps divert chip flow, limiting direct contact with the rake face and further lowering crater wear.

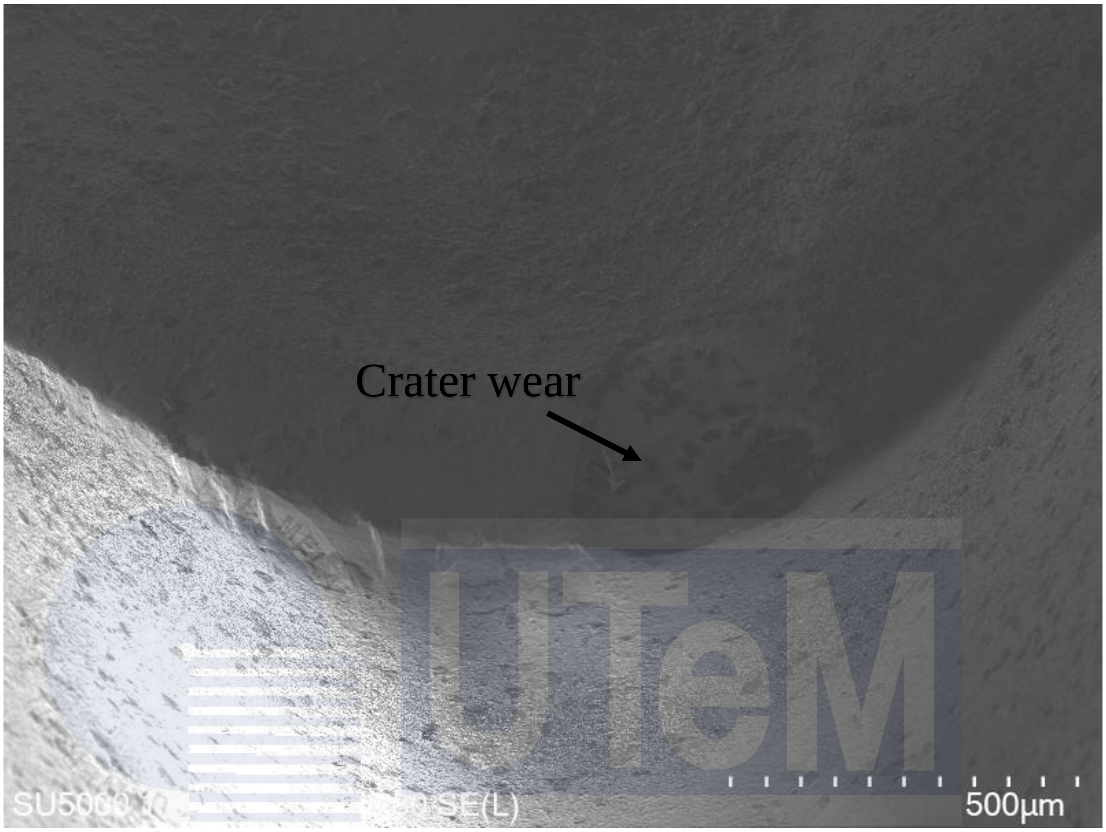


Figure 4.13: Crater wear that formed on 80˚ trigon carbide tool under dry condition

4.5 Tool Wear Progression of 3 Difference Cutting Tool

X. Lei et al. (2019) found that every cutting point shows a significant difference in the wear rate and cutting force between bigger and lower rake angle carbides. The 80˚ rhombic tool exhibits lower cutting forces, mostly due to reduced temperature in the cutting zone and less tool wear during the turning operation, even if a smaller rake angle may make chip removal more difficult. The heat generated at the cutting zone not only results in worse machined surface smoothness, but it also alters the microstructure of tool alloy, induces residual stresses at the top layer of the machined workpiece surface, and activates the tool wear rate.

Regarding the figure below, show the wear progression for 3 uncoated carbide in dry condition for a different combination of cutting parameter. The development of wear progression may be divided into three stage (early stage, middle stage and ultimate stage). When the cutting tool initially contacts the hard workpiece at the start of the cutting operation, the cutting edge is somewhat worn due to the early rubbing and friction. Combinations of adhesion, abrasion, and minor chipping brought on by tension can cause this wear. The wear rate stabilises throughout the middle period. The predominant wear processes may alter, and the tool shape has somewhat modified. This stage of wear progression can continue for a considerable amount of the tool's life, with wear increasing gradually but reliably. When the cutting tool reaches a crucial point, the final step occurs. Wear rates dramatically increase as cutting pressures may rise, surface finish quickly deteriorates, and the likelihood of the cutting-edge breaking increases. This stage is the end of the tool’s effective life.

The mechanical friction and chemical reaction at tool-chip-workpiece contact interfaces deteriorated due to the induced high cutting temperature rises and cutting forces, which the wear of the tool machining performance and surface topography Ozel et al. (2011). During hard turning, the intense friction between cutting tool, workpiece and crip formation creates extreme heat and pressure. The crucial contact zones where these components converge are weakened by these adverse surroundings.

4.5.1 Rhombic 80˚ Under Dry Condition

Figure 4.14 show the wear progression at 90 m/min cutting speed with 0.1 mm/rev feed rate. In the early stages of cutting, the wear progression is increased rapidly until Vb approaches the value of 0.15 mm. The observation of tool wear progression slowly increased between range value of Vb 0.15 to 0.2 mm. Regarding to the figure 4.14 and 4.15, the value of the tool wear in 0.1 mm/rev is highest (0.165 mm) compare to 0.2 mm/rev with same cutting speed (90 m/min) and constant depth of cut. The trend of the wear progression graph quietly similar that slowly at value of Vb between 0.05 – 0.1 mm in cutting speed (120 m/min) on figure 4.16 and 4.17. The tool life value at 120 m/min cutting speed is increasing for both feed rate compares to 90 m/min cutting speed.

Figure 4.18 and 4.19 show the wear progression value at 150 m/min cutting speed in dry condition. From the experimental of cutting speed 150 m/min, feed rate 0.2 while constant depth of cut 0.4mm. The highest value of wear progression is 0.105 mm. While in figure 4.18 also image the trend of the wear progression of 80˚ rhombic uncoated carbide. When the run the machining in low feed rate (0.1 mm/rev), the value of wear progression is 0.093 mm. The value of the tool life also increased when apply in lower feed rate.

In cutting speed 120 m/min with 0.2 mm/rev feed rate produce the lowest of tool wear progression are recorded 0.042 mm while this is the suitable combination parameter to get efficiency in hard turning machining. That are supported with Zhao et al. (2023) The strong cutting forces generated during the initial high-speed cutting of Ti-6Al-4V placed significant mechanical pressures on the cutting tools. The tool wear process was expedited by the high mechanical stresses. In the metal cutting elevated temperature and high value of both normal and shear stresses between the tool and workpiece material at the cutting edge contributes to the development of tool wear Fatima A. et al. (2023). Tool material, coatings, cutting temperature, and cutting parameters may all be changed to reduce tool wear Binder M. et al. (2015).

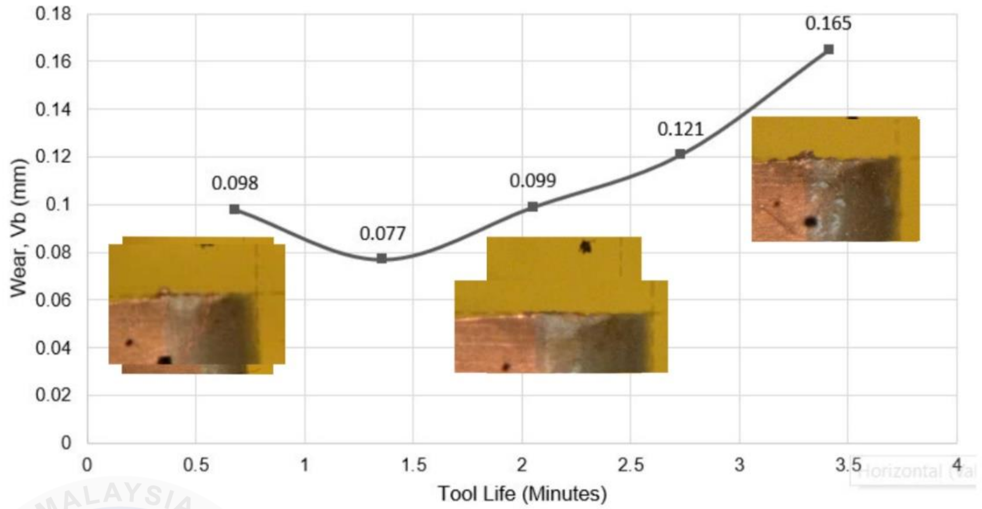


Figure 4.14: Wear progression on 80˚ rhombic (Vc = 90 m/min, f = 0.1 mm/rev)

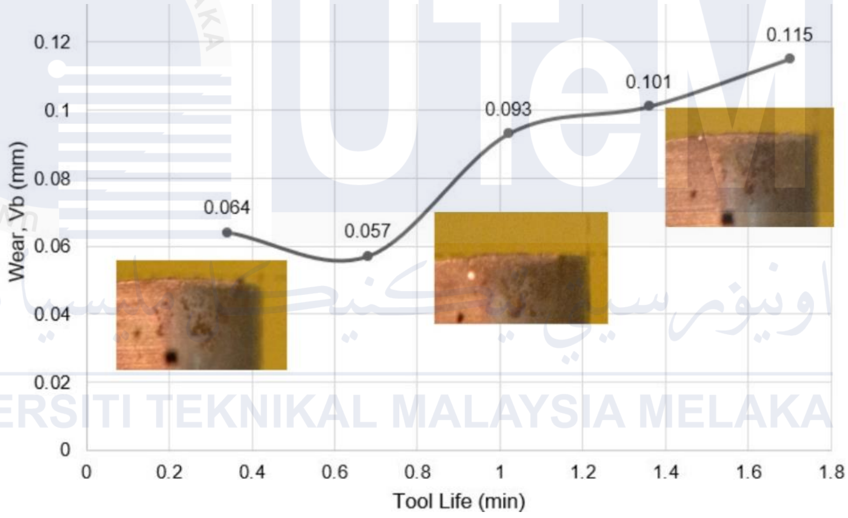


Figure 4.15: Wear progression on 80˚ rhombic (Vc = 90 m/min, f = 0.2 mm/rev)

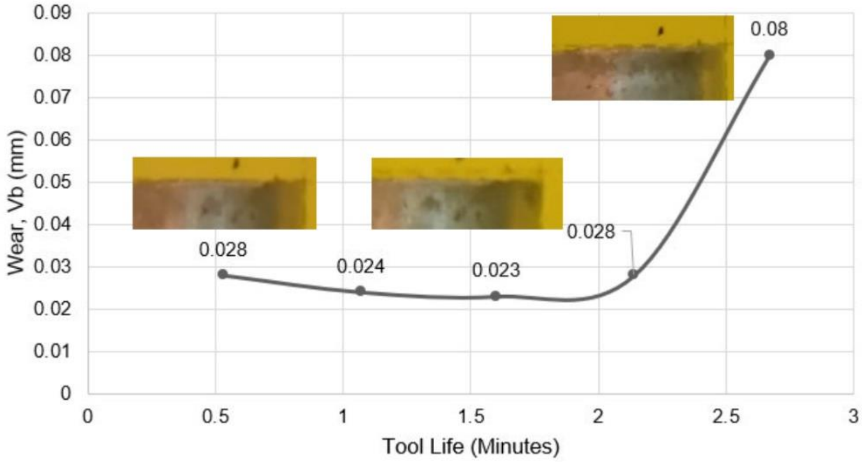


Figure 4.16: Wear progression on 80˚ rhombic (Vc = 120 m/min, f = 0.1 mm/rev)

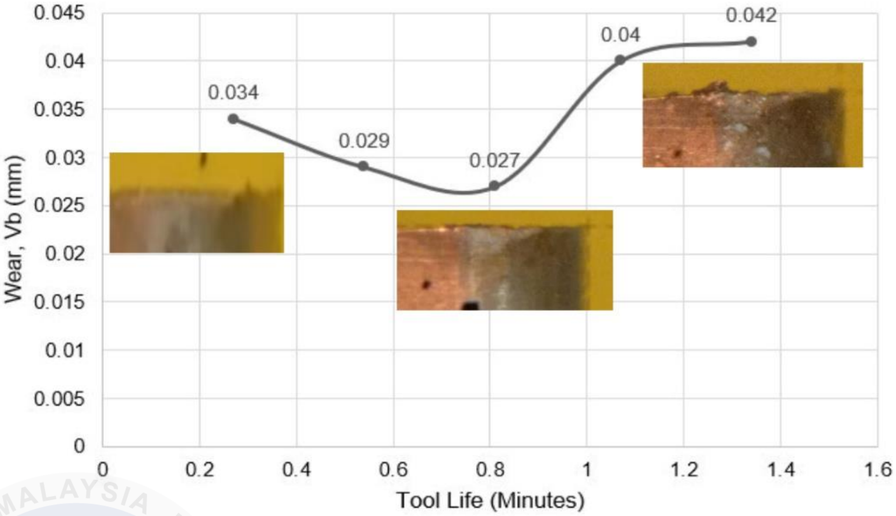


Figure 4.17: Wear progression on 80˚ rhombic (Vc = 120 m/min, f = 0.2mm/rev)

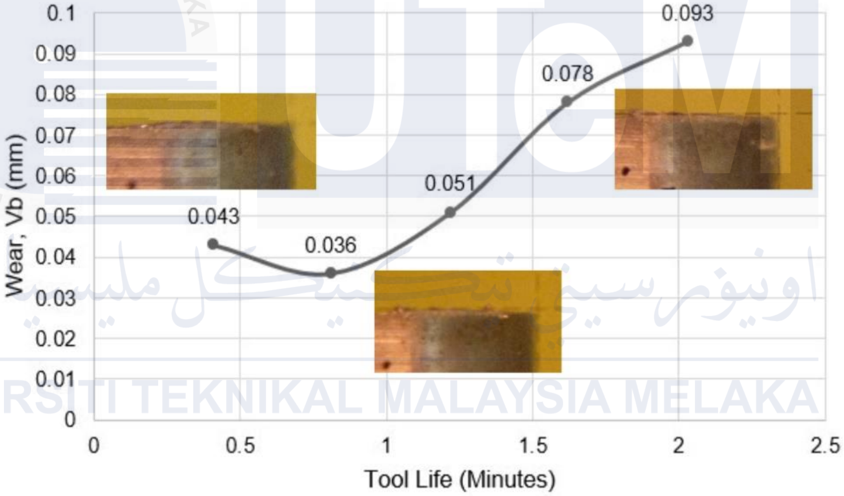


Figure 4.18: Wear progression on 80˚ rhombic (Vc = 150 m/min, f = 0.1mm/rev)

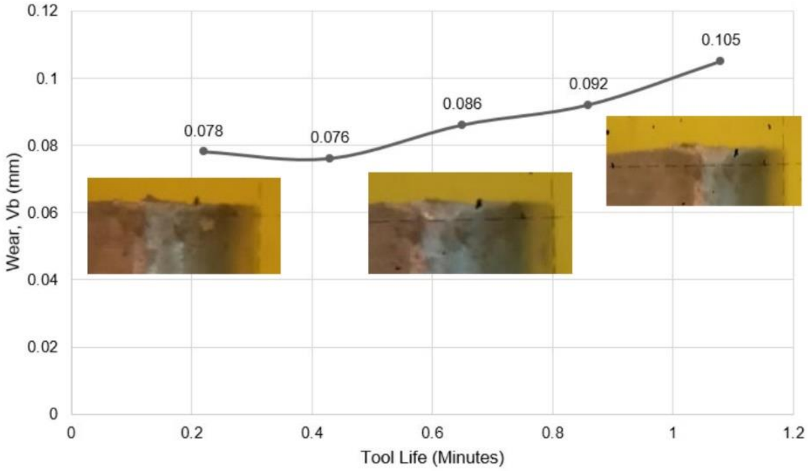


Figure 4.19: Wear progression on 80˚ rhombic (Vc = 150 m/min, f = 0.2mm/rev)

4.5.2 Rhombic 35˚ Under Dry Condition

Figure 4.20 and 4.21 show the tool wear progression value for 35˚ rhombic uncoated carbide in dry condition at cutting speed 90 m/min with 2 value of feed rate (0.1 and 0.2 mm/rev). By observation of the wear progression in this figure have same of the trend of graph in figure 4.18 and 4.19. But the wear progression of the cutting tool is higher than limit Vb 0.3 mm. The value of wear progression is 0.48 mm at 0.1 mm/rev feed rate and the Vb 0.3 mm are achieve at second run which is in 40 mm length. At figure 4.22 and 4.23, the value of wear progression is increased rapidly to 0.519 mm at 120 m/min cutting speed with 0.2 mm/rev of feed rate.

The value of wear progression in figure 4.24 and 4.25 also have similar trend with figure 4.23. Refer to the trend of the wear progression, it will be concluded that the pattern of tool wear in 35˚ of rhombic is rapid in wear progression for all the combination of parameter. There has highest value in wear progression compare to 80˚ of rhombic in dry machining condition. All the cutting speed such as 90, 120 and 150 m/min have pair with 2 value of feed rate (0.1 and 0.2 mm/rev) to make comparison for effect of wear progression, and plotted the graph for each combination parameters.

Zerti et al. (2017) said that increasing the approach angle is an insignificant contribution on the main cutting force. The cutting-edge cracking is happened on the smaller rake angle tool but no crack is seen on the larger rake angle tool. That are verifies the effect of the distributed cutting for protecting the cutting edges and slowing down the wear progression rate Lei et al. (2019). The structures at the rake face the spot serve as both a debris catcher and a reservoir for cutting fluid. This structural activity has assisted in lessening the development of crater wear. That opinion is agreed by previous studies (Wasif et al. 2023).

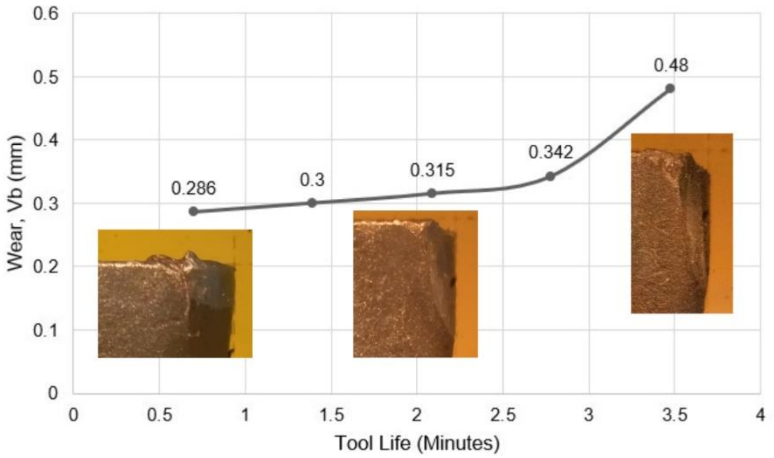


Figure 4.20: Wear progression on 35˚ rhombic (Vc = 90 m/min, f = 0.1 mm/rev)

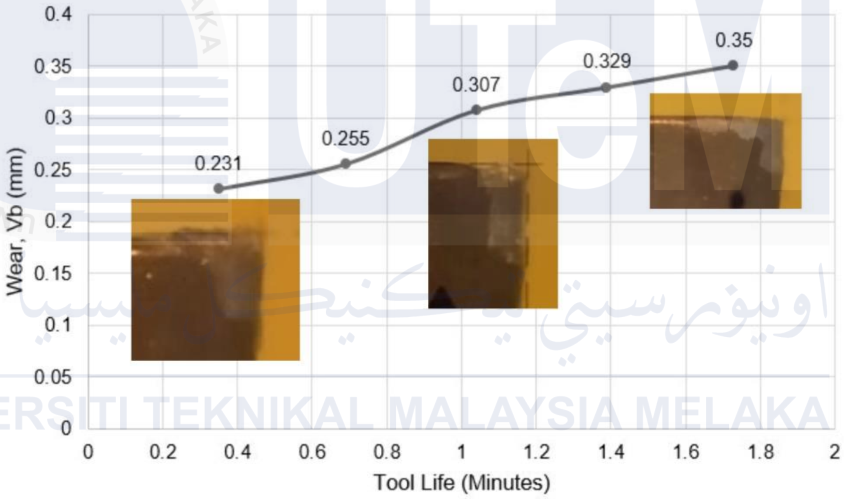


Figure 4.21: Wear progression on 35˚ rhombic (Vc = 90 m/min, f = 0.2 mm/rev)

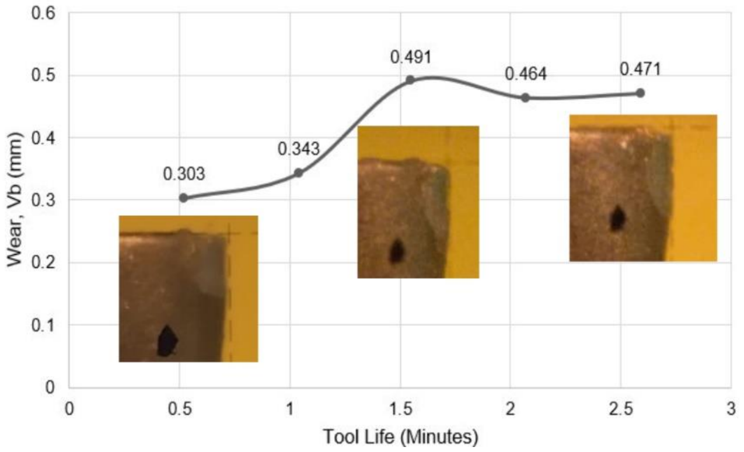


Figure 4.22: Wear progression on 35˚ rhombic (Vc = 120 m/min, f = 0.1 mm/rev)

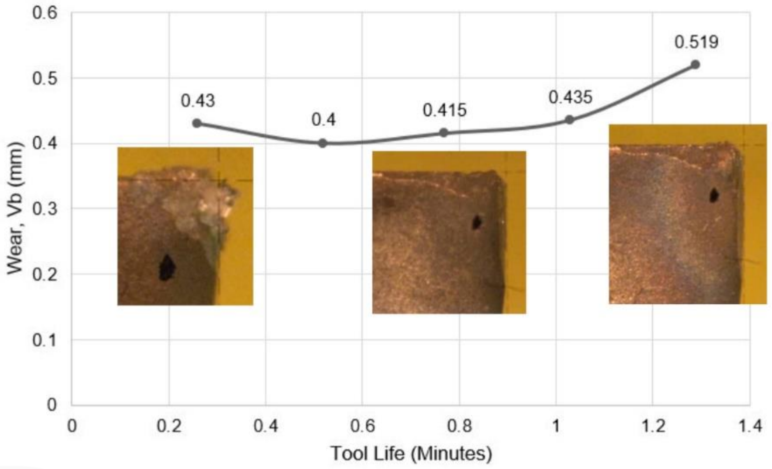


Figure 4.23: Wear progression on 35˚ rhombic (Vc = 120 m/min, f = 0.2 mm/rev)

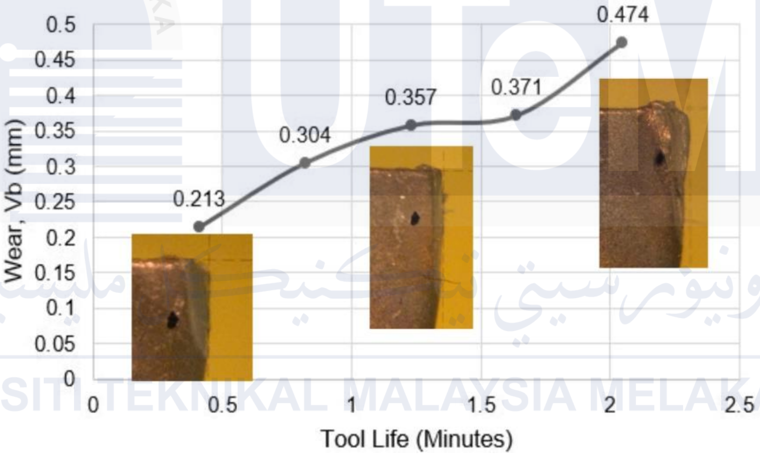


Figure 4.24: Wear progression on 35˚ rhombic (Vc = 150 m/min, f = 0.1 mm/rev)

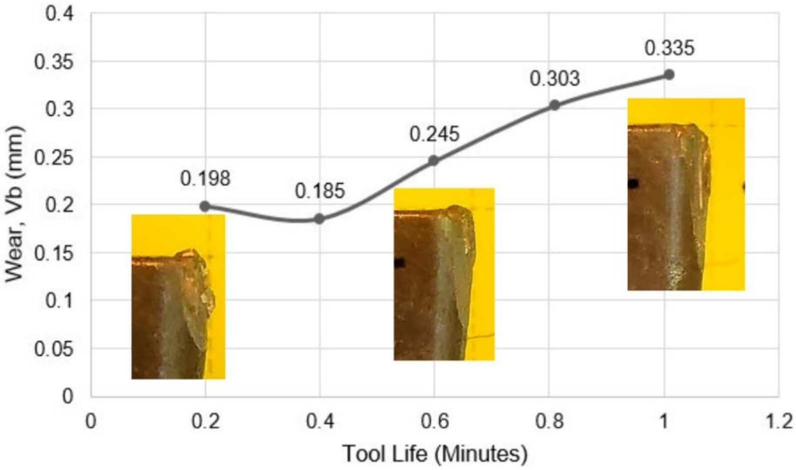


Figure 4.25: Wear progression on 35˚ rhombic (Vc = 150 m/min, f = 0.2 mm/rev)

4.5.3 Trigon 80˚ Under Dry Condition

Figure 4.26 and 4.27 depicts the wear progression of uncoated carbide in 80˚ trigon during run under dry condition with a cutting speed 90 m/min and depth of cut of 0.4 mm. According to prior study, the development of flank wear rises in the early stage such as in figure 4.26 to 4.31. (Zhao J. et al. 2023; Kumar R. 2018; Zeqiri F. et al. 2022) support this hypothesis by discovering that the increasing the cutting speed and feed rate will affect the increasing tool wear progression of cutting tool. The wear rate then progressively rises and becomes steady in the middle stage of wear. During the last stage of wear, the wear increased sharply and there is fast wear. Figure 4.27 clearly shows the existence of accelerated wear with 0.146 mm value of wear.

Figure 4.29 show the wear progression value at 120 m/min cutting speed in dry condition of 80˚ trigon uncoated carbide. From the experimental of cutting speed 120 m/min, feed rate 0.2 while constant depth of cut 0.4mm. The highest value of wear progression is 0.177 mm. While in figure 4.30 and 4.31 also image the trend of the wear progression of 80˚ trigon uncoated carbide at cutting speed 150 m/min. When the run the machining in low feed rate (0.1 mm/rev), the value of wear progression is 0.187 mm. The value of the tool life also increased when apply in lower feed rate which is 2 minutes. Similarly, Giang L. H. et al. (2021) and Zhou H. et al (2019) analysed the increasing the cutting-edge angle will reduce tool wear progression on AISI 1055 hardened steel and AISE 52100 hardened steel.

In the study by Baizeau et al. (2015), the effects of tool geometry were also investigated. It was found that, despite increasing cutting forces, using a honed and chamfered tool with a null or negative rake angle allows for the creation of an appropriate shear angle and prevents undesirable ploughing effects in the workpiece material. By increasing the number of chamfers, the tool wear is reduced and the tool life increased, while there is no chamfer number effect on residual stresses (Ventura et al. 2020; Cappellini C. et al. 2021). While Denkena et al. (2017) stated that in machining of different part aerospace alloys with coated and uncoated carbide inserts. The tool was modified with a flank undercut that will increased the compression stresses on it and directly improving the tool life up to 70% when machining titanium alloys.

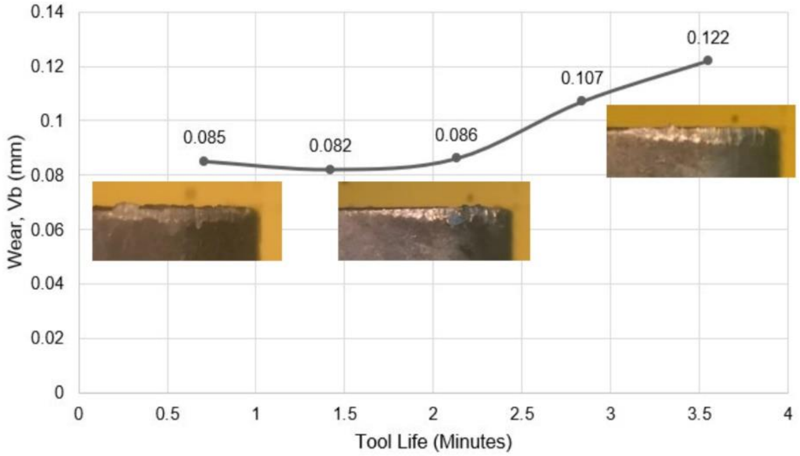


Figure 4.26: Wear progression on 80˚ trigon (Vc = 90 m/min, f = 0.1 mm/rev)

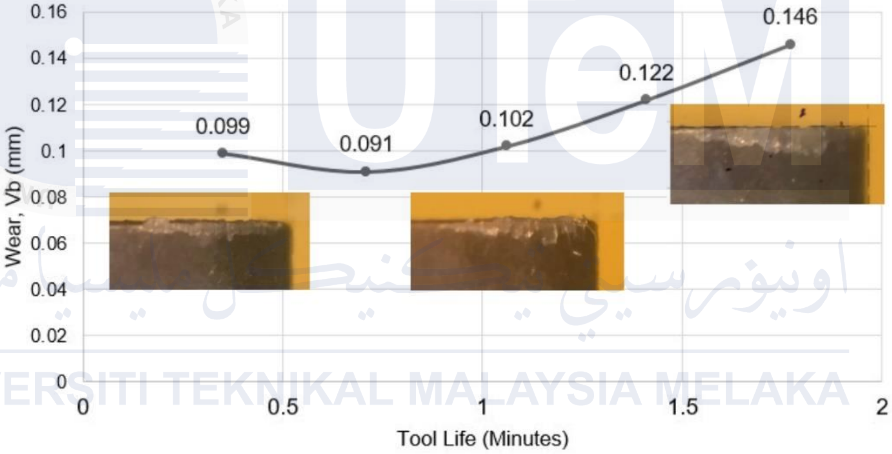


Figure 4.27: Wear progression on 80˚ trigon (Vc = 90 m/min, f = 0.2 mm/rev)

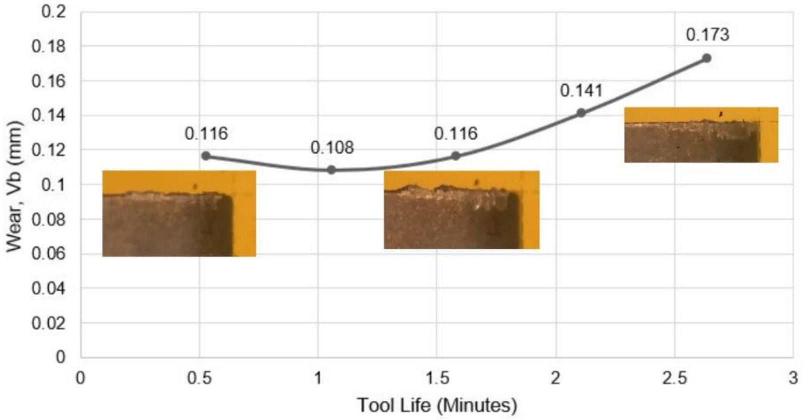


Figure 4.28: Wear progression on 80˚ trigon (Vc = 120 m/min, f = 0.1 mm/rev)

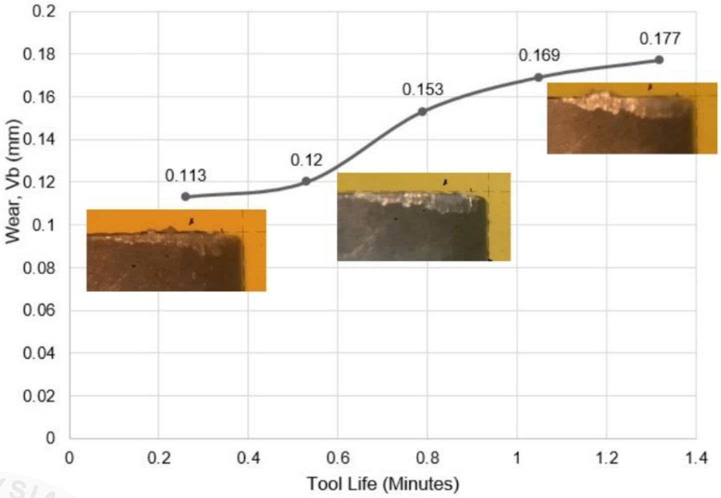


Figure 4.29: Wear progression on 80˚ trigon (Vc = 120 m/min, f = 0.2 mm/rev)

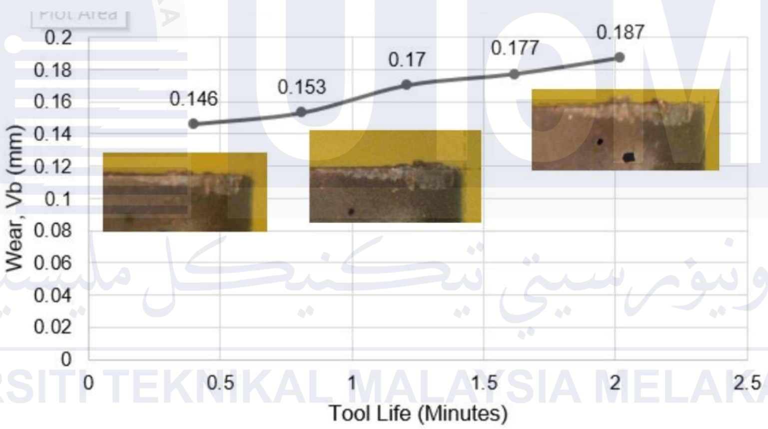


Figure 4.30: Wear progression on 80˚ trigon (Vc = 150 m/min, f = 0.1 mm/rev)

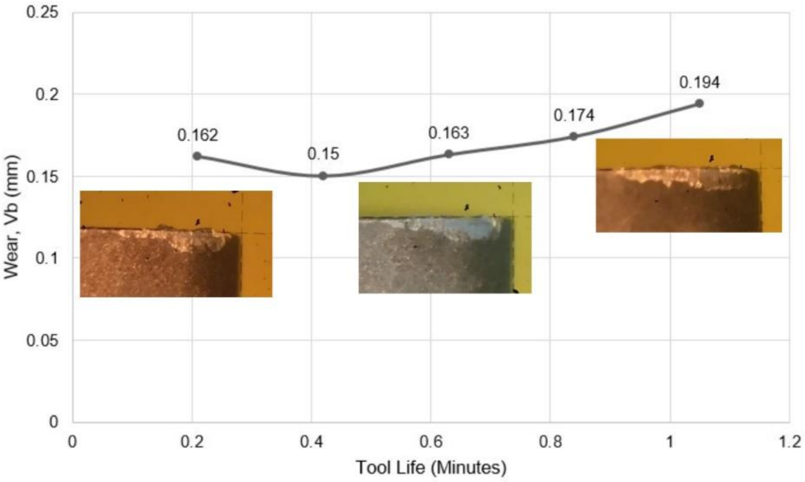


Figure 4.31: Wear progression on 80˚ trigon (Vc = 150 m/min, f = 0.2 mm/rev)

4.5.4 Summary and Comparison the Tool Wear Progression

Based on the observation in figure 4.14 to 4.31, observed the progress of wear flank of the hard turning under dry condition for difference geometries uncoated carbide (80˚ rhombic, 35˚ rhombic and 80˚ trigon). From the figure, it is found that the pattern of wear progression can be divided into 3 stage, the initial stage, the intermediate stage and final stage of cutting tool. At initial stage, the wear rate is increase rapidly, while the intermediate stage of cutting tool are become constantly increase of wear rate. The final stage of cutting tool, the wear rate are increases dramatically and it can cause the higher value of surface roughness workpiece. Figures 4.20 to 4.25 show that increasing of the cutting speed 90 to 150 m/min 35˚ rhombic affect the increasing of tool wear value. In figure 4.22 and 4.23, at 120 m/min cutting speed the value of wear Vb are archieve at 40 mm length of turning which is above 0.3 mm wear rate valueSurface roughness values and tool wear progression is reduced by the increased rake angle's efficacy. (Gariani S., Dao T. and Lajili A. 2023) prove the statement with their study in turning AISI 304L. This is because of its special tool tip shape, which might reduce tool wear.

Figure 4.32 show that the comparison 3 uncoated carbide with picture of tool wear in 100 mm length of turning. 80˚ rhombic is the effectively insert in 150 m/min cutting speed in turning titanium alloy, Ti-6Al-4V ELI under dry condition with lowest tool wear value. Followed with 80˚ trigon cutting tool with 0.194 wear rate value. In recent times, carbide tools featuring a wiper geometry have gained popularity as a viable substitute for traditional tools because of their improved nose geometry. This has a wide radius of curvature, which makes it possible to apply high feed rates and increase output (Abbas A. et al. 2020; Muthuswamy P. 2022). The comparison of 3 uncoated carbide at cutting speed 120 m/min was shown in figure 4.33. The tool wear progression in 120 m/min cutting speed for 80˚ rhombic insert is lower than 150 m/min cutting speed with 0.063 mm difference value. That are prove by Zeqiri F. et al. (2022) that increasing cutting speed and feed rate will be increased the tool wear of cutting tool. 80˚ rhombic shape is the effectively cutting tool for turning titanium alloy.

Figure 4.32: Comparison in 150 m/min cutting speed with 0.2 mm/rev feed rate

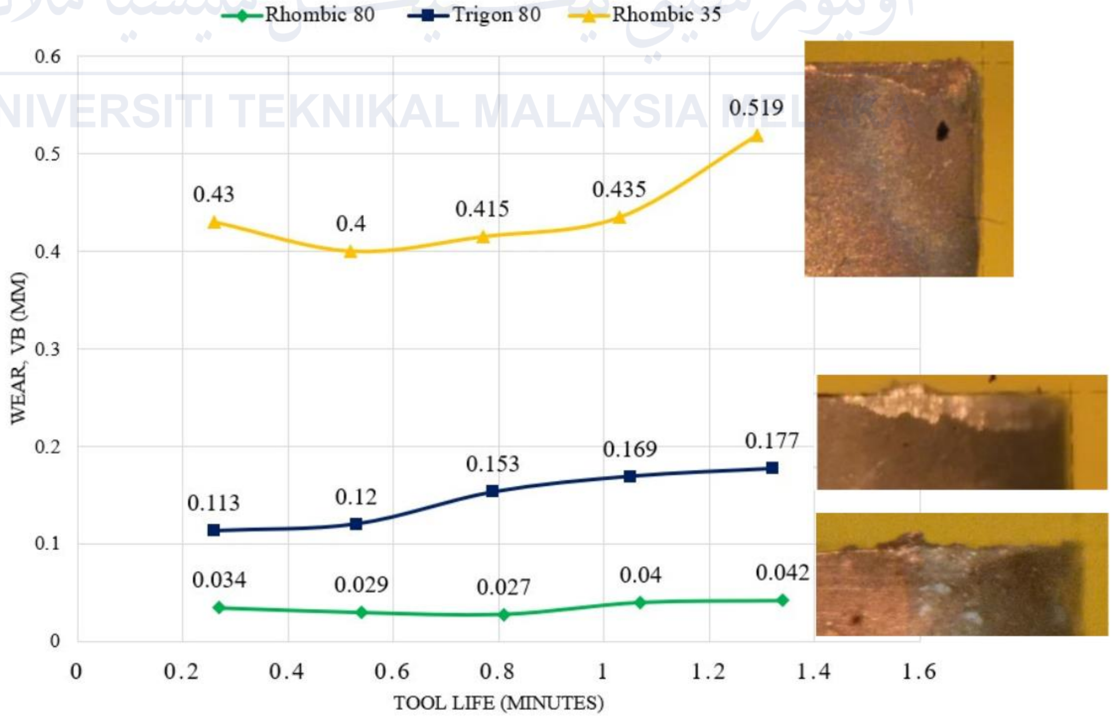


Figure 4.33: Comparison in 120 m/min cutting speed with 0.2 mm/rev feed rate

4.6 Summary

This chapter presents the results of the experiments and discussion on the performance difference geometries cutting tool in turning titanium alloy, Ti-6Al-4V ELI under dry condition. The issues discussed in this chapter are based on the objective of the project study. From the research study, the 80˚ rhombic cutting tool record the highest tool life in turning titanium alloy, Ti-6Al-4V ELI. Observations on the tool wear found in 35˚ rhombic cutting tool with highest value of tool wear progression but the suitable cutting tool with lower tool wear value is 80˚ rhombic followed with 80˚ trigon cutting tool.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The present research work was conducted to comparative study of performance difference geometries carbide tool in turning titanium alloy Ti-6Al-4V ELI. Discussion that has been presented, some conclusions that can be made to summarize all the results of the study and meet the objective requirements are:

I. The first objectives are to investigate the performance of tool life value on difference geometries un-coated carbide cutting tools. The highest tool life is 80˚ rhombic carbide while the lowest tool is recorded in 80˚ trigon. The effect of feed rate value at (0.1 mm/rev) is clear on tool life giving shorter tool life in all cutting speed and 3 difference geometries carbide. Tool life is inversely correlated with cutting speed, and for all carbide geometries, this relationship is stronger than that of feed rate. It is vital to comprehend the significance of each of these factors in order to acquire a deeper comprehension of the turning process. The factors that affect tool life throughout the turning process are too many to identify, including feed rate, cutting speed, depth of cut, workpiece geometry, and cutting-edge geometry.

II. The second objectives are to analyze tool failure mode and tool wear pattern on the cutting tool during turning titanium alloy Ti-6Al-4V ELI under dry conditions. The lowest tool wear is 80˚ rhombic carbide while the highest tool wear is 35˚ rhombic. The difference type of geometry carbide is mainly causing in tool wear value for hard turning.

5.2 Recommendations

The uniqueness and advantages of Ti-6Al-4V ELI titanium alloy have made it a very suitable choice for big scale industries such as petroleum, aerospace, and nuclear production equipment. Consequently, several research projects can be done on this alloy material in order to achieve the optimal quantities of cutting tool and cost to investing in machining. There are some suggestions that can be made for this experimental test in the future. Among them are:

I. 80˚ rhombic cutting tool are the best insert in turning hard materials. It is recommended using this cutting tool in turning titanium alloy Ti-6Al-4V ELI. A study should be conducted to obtain a comparison of the value of tool wear progression and tool life between larger rake angle of cutting tool such as between 60˚ triangle and 55˚ rhombic

II. The optimum machining by difference geometries cutting tool should be investigate the value of the tool wear with cutting force between difference geometries of the cutting tool. It is recommended to use this method for titanium alloy escape in theory it can be reduce tool wear when used larger rake angle of cutting tool. The study needs to be done by obtain a comparative value of tool wear progression between difference geometries cutting tool.

5.3 Sustainability Development

Several aspects of sustainable development have been via the study on turning process utilising with compared the difference geometries cutting tool which are:

1. By using dry machining techniques is an environmentally friendly to minimizing the environmental impact.
2. The reducing tool wear progression can be improved by applying the larger rake angle of cutting tool in hard turning.

3. The properties of titanium itself will lead to better performance by using the best selected of geometries cutting tool as it was applying in a lot of sectors such as aerospace, petroleum equipment and automotive.

5.4 Lifelong Leaning Element

In the dynamic world of research, lifelong learning aspect is an essential tool. Demanding researchers to continuously learn to keep pace with the new discoveries, methodologies and technologies. This not only prevents them from falling behind, but also welcome to fresh research avenues by allowing them to develop new technique. Lifelong learning also fosters creativity and innovation by exposing researchers to diverse ideas, researchers who actively cultivate their knowledge and skill to secure finding, publish their work and advance their careers. In order to manufacturing engineering such as Computer Numerical Control (CNC), characteristics of material and many orders has been gained by analysing the mechanical properties and compare the study difference cutting tool of performance in turning machining.

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