OPTIMIZATION OF TOOL LIFE IN MILLING

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Dedicated to my beloved father, mother,sister and brother

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ABSTRACT

This paper discuss of the Optimization of Tool Life in Milling. The objective of the paper is to obtain an optimal setting of turning process parameters –cutting speed, feed and depth of cut, which may result in optimizing tool life of TiN coated carbide inserts while milling aluminium 6061. Data is collected from FANUC Robodrill CNC milling machines were run by 15 samples of experiments. A dimensional-accuracy model for the end milling of aluminum alloys under dry conditions is presented. To build the quadratic model and minimize the number of experiments for the design parameters, response surface methodology (RSM) with a Box-Behnkin method is used to design the table in MINITAB packages. The inputs of the model consist of feed, cutting speed and depth of cut while the output from the model is tool life and tool wear was measured using Image Analyzer microscope.The model is validated through a comparison of the experimental values with their predicted counterparts. A good agreement is found where from the RSM approaches which reliable to be use in tool wear prediction. The direct and interaction effect of the machining parameter with tool wear were analyzed and plotted, which helped to select process parameter in order to reduce tool wear which ensures quality of milling. It is shown that the tool wear in end milling decreases with the increase in feed, radial depths of cut and cutting. From the experiment it is found that the effect of axial depth of cut on tool life is not so significant. The speed effect is dominant followed by the feed and the axial depth of cut. For end-milling of aluminium alloy 6061, the optimum condition that is required to maximize the coated carbide tool life are as follow: cutting speed of 180m/min, federate of 0.2 mm/rev, axial depth of 1.5 mm.

ABSTRAK

Kertas kajian ini membincangkan tentang mengoptimum kehidupan mata alat dalam proses pengilingan. Objektif kertas kerja ini adalah untuk mendapatkan gubahan parameter yang optimal oleh mesin penggilingan-kelajuan pemotongan,nilai suapan dan kedalaman pemotongan, yang dimana akan member kesan dalam mengoptimum sisipan mata alat TiN coated carbide semasa memesin aluminium 6061. Data di kumpul dari mesin menggiling CNC FANUC Robodrll dimana dijalankan menggunakan 15 sampel eksperiment. Model dimensi ketepatan untuk proses pengiligan hujung untuk aluminium aloi dibawah kondisi kering digunakan. Untuk membina model kuadratik dan mengurangkan jumlah eksperimen untuk rekacipta parameter, response surface methodology (RSM) dengan cara Box-Behkin digunakan untuk mereka-cipta jadual di dalam MINITAB. Penghasilan model terdiri daripada nilai suapan, kelajuan pemotongan dan kedalaman memotong dimana outputnya dari model ini adalah kehidupan mata alat dan kehausan mata alat di ambil dengan menggunakan Image Analyzer mikroskop. Kesan laluan dan interaksi parameter pemesinan dan kehausan mata alat di analisis dan di plot graf dengan, dimana ianya membantu untuk memilih proses parameter dengan tujuan untuk menurangkan kehausan mata alat dan memastikan kualiti penggiligan. Itu ditunjukan yang mana kehidupan mata alat dalam proses menggiling hujung rendah dengan menambahkan nilai pada suapan, jumlah kedalaman pemotongan dan kelajuan pemotongan. Ini juga didapati bahawa jumlah kedalaman pemotongan mempunyai signifikan yang paling banyak mempengaruhi kehausan mata alat didalam proses pemotongan hujung terhadap aluminium aloi.

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f	Feed Rate, mm/rev
d	Depth of Cut, mm
V_C	Cutting Speed, m/min
L	Cutting Length, mm
D	Workpiece Diameter, mm
N	Spindle Speed, rpm
Vc	Crater Wear, mm
Vb	Flank wear, mm
μ	Mean

LIST OF ABBREVIATIONS

DOE	Design of Experiment
CNC	Computer Numerical Control
TiN	Titanium Nitride
CVD	Chemical vapor deposition
PVD	Physical vapor deposition
SEM	Scanning Electron Microscope
PSO	Particle Swarm Optimization
AISI	American Iron and Steel Institute
ISO	International Organization for Standardization

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

The development of miniaturised technologies has become a global phenomenon that continues to make an impact across a broad range of applications that encompasses many diverse fields and industries. One of the technologies used to create these miniaturized components is milling. In order to optimise the economic performance of metal cutting operation, efficient quantitative and predictive models that establish the relationship between a big of independent parameters and output variables are required for the wide spectrum of manufacturing processes, cutting tools and engineering materials currently used in industry.

Furthermore, it has been observed that the improvement in the output variables such as tool life, cutting forces and surface roughness through the optimisation of input parameters such as feed rate, cutting speed and depth of cut may result in significant economical performance of machining operations. One of these output variables that may have either direct or indirect indications on the performance of other variables such as tool wear rate, machined surface characteristics and machining cost is cutting force.

1.2 PROBLEM STATEMENT

Optimum tool life is great concern in manufacturing environments where, economy of machining operation plays a key role in competitiveness in the market. The milling process compare to the other metal machining process is quite slow thus having a low production rate. Although NC machines function is to reduce lead times considerably, the machining time is almost the same as conventional machining where machining parameters are selected from machining databases or handbooks.

Milling process can be used on the non-ferrous and ferrous material. Inaccuracy of cutting tool contribute to poor surface finish, tool damage, chatter, dimensional accuracy and many other problems that contribute to low productivity and much time to be wasted. (Kalpakjian and Schmid 2003).

One of the popular cutting tools that are used is coated carbide inserts. This study helps to improve the performance of milling process by using coated carbide tool as a cutter for the optimum performance using. This project also can helps mass production machining in our industry (S. Krar et al 1994).

1.3 PROJECT OBJECTIVE

The objective of this project is to:

(i) Investigate and predict the type of tool wear in end milling using CNC milling machine of aluminum alloy 6061.

(ii) Determine the optimum parameters to increased tool life for milling to maximize the production rate and minimum production cost in industry.

1.4 PROJECT SCOPE

The scope of project covered study and analysis about tool life and the project consists of this below:

(i) The research is focus on milling of Aluminum 6061 in end milling under dry condition.

(ii) Machining parameters considered are depth of cut, federate, and cutting speed. Constant feed rate and depth of cut were set based on literature.

(iii) The cutting speed varied range from 100,140 and 180 m/min. Feed range from 0.1, 0.15, 0.2 mm/tooth and axial depth range is 1, 1.5,2 mm.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Tool life is an important aspect commonly considered in evaluating the performance of a machining process. In addition, tool life estimates and the corresponding economic analysis are among the most important topics in process planning and machining optimization. The coefficients are also a function of tool wear, which typically results in increased cutting forces as the tool wears. The need for measurement of all cutting force component arises from many factors, but probably the most important is need correlation with the progress of tool wear. It is well known that during the machining, the cutting parameters such as cutting speed, feed rate and depth of cut often present a deviation from the calculated values. Furthermore, it has been observed that the improvement in the output variables may result in a significant economical performance of machining operations. The aspect need to be considered for the tool life is cutting force on the workpiece and the temperature during machining that are subjected by the cutter tools and tool wear can be measured by using microscope (Prickett, and Johns, 1999).

2.2 MILLING MACHINE

Milling is the process of machining flat, curved or irregular surface by feeding the workpiece against a rotating cutter containing a number of cutting edges. Milling process consists of a motor driven spindle, which mounts and revolves the milling cutter and a reciprocating adjustable worktable, which mounts and feeds the workpiece.

Milling machines are basically classified as vertical or horizontal. These machines are also classified as knee-type, ram-type, manufacturing or bed type, and planer-type. Most milling machine have self-contained electric drive motors, coolant systems, variable speeds and power-operated table feeds.

Milling machine is a machine tool that cuts metal with multiple-tooth cutting tool called a milling cutter. The workpiece is fastened to the milling machine table and is fed against the revolving milling cutter. The milling cutter can have cutting teeth on the periphery or side or both. (S. Krar et al, 1994).

Milling machine can be classified into three main headings:

i. General Purpose machines – these are mainly the column and knee type (horizontal and vertical machines).
ii. High Production types with fixed beds – (horizontal types)
iii. Special purpose machines such as a duplicating, profiling, rise and fall, rotary table planetary and double end types.

Milling attachments can also be fitted to other machine tools including lathes planning machines and drill bench presses can be used with milling cutters. Milling machine is one of the most versatile conventional machine tools with a wide range of metal cutting capability. Many complicated operations such as indexing, gang milling and straddle milling can be carried out on a milling machine (Kalpakjian and Schmid 2003).

2.3 CLASSIFICATION OF MILLING

2.3.1 Slab Milling

In slab milling, also called peripheral milling, the axis of cutter rotation is parallel on the workpiece surface to be machined .Cutter for slab milling may have straight or helical teeth resulting in respectively, orthogonal or oblique cutting action. The helical tooth on the cutter is preferred over straight teeth because the load on the tooth is lower, thus smoother operation and reducing tool force and chatter (S. Krar et al, 1994).

2.3.2 Face Milling

In face milling, the cutter is mounted on a spindle having an axis of rotation perpendicular to the workpiece surface (Kalpakjian and Schmid 2003). The milled surface results from the action of cutting edges located on the periphery and face of the cutter.

2.2.3 End Milling

Flat surface as well as various profiles can be produced by end milling. The cutter in end milling has either straight or tapered shanks for smaller and larger cutter sizes respectively. The cutter usually rotates on an axis perpendicular to the workpiece, although it can be tilted to machine-tapered surface (Kalpakjian and Schmid 2003).

2.4 MECHANISM OF MILLING

2.4.1 Up Milling (conventional milling)

The safe way to machine a piece of metal using a horizontal miller is to feed the metal into the cutter, against its rotation. This is called up-milling and it’s the technique used in school workshops. The metal must be held very firmly in a large machine vice to ensure it is extremely tight. In up milling the maximum chip thickness is at the end of the cut. The advantages of using up milling are the cutting process is smooth, provide that the cutter teeth are sharp. However they may be a tendency for the tool to chatter and the workpiece has to pull upward (Kalpakjian and Schmid 2003).

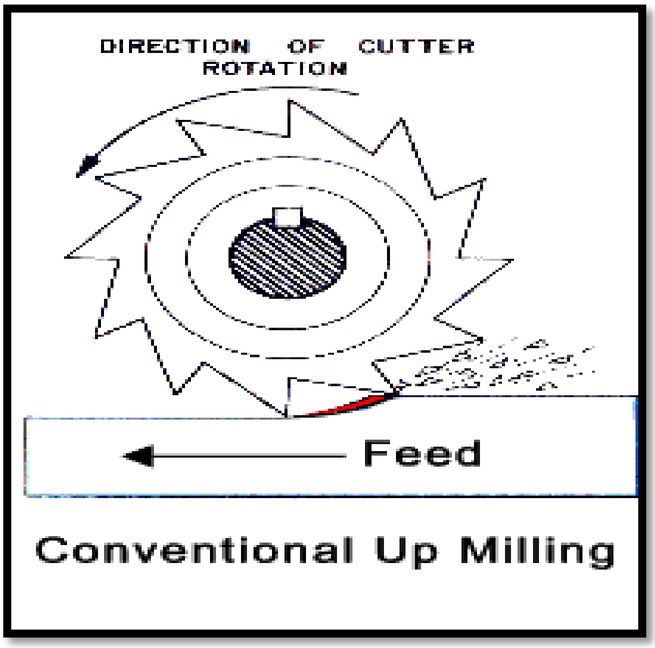

Figure 2.1: Up Milling

Source: Kalpakjian and Schmid 2003

2.4.2 Down Milling (climb milling)

Down milling is also referred to as climb milling. The direction of cutter rotation is same as the feed motion. For example, if the cutter rotates counter clockwise, the workpiece is fed to the right in down milling. The advantage is that the downward components of the cutting force hold the workpiece in place. However it is not suitable for the machining of a workpiece having a surface scale such as hot worked metals, forgings and casting. The scale is hard and abrasive and can cause excessive wear and damage to the cutter teeth, shortening tool (Kalpakjian and Schmid 2003).

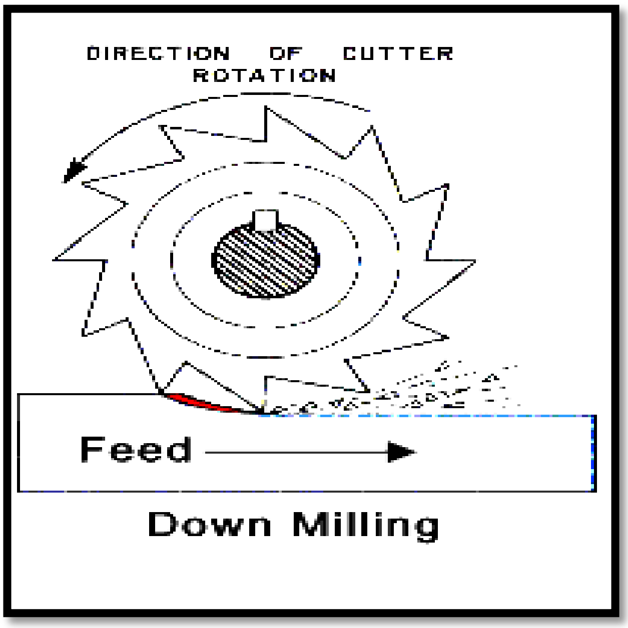

Figure 2.2: Down Milling

Source: Kalpakjian and Schmid 2003

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2.5 TYPE OF MILLING MACHINE

2.5.1 Vertical Milling Machine

In the vertical mill the spindle axis is vertically oriented. Milling cutters are held in the spindle and rotate on its axis. The spindle can generally be extended (or the table can be raised/lowered, giving the same effect), allowing plunge cuts and drilling. There are two subcategories of vertical mills: the bedmill and the turret mill. Turret mills, are generally smaller than bedmills, and are considered by some to be more versatile. In a turret mill the spindle remains stationary during cutting operations and the table is moved both perpendicular to and parallel to the spindle axis to accomplish cutting. In the bedmill, however, the table moves only perpendicular to the spindle's axis, while the spindle itself moves parallel to its own axis. Also of note is a lighter machine, called a mill-drill. It is quite popular with hobbyists, due to its small size and lower price. These are frequently of lower quality than other types of machines (Kalpakjian and Schmid 2003).

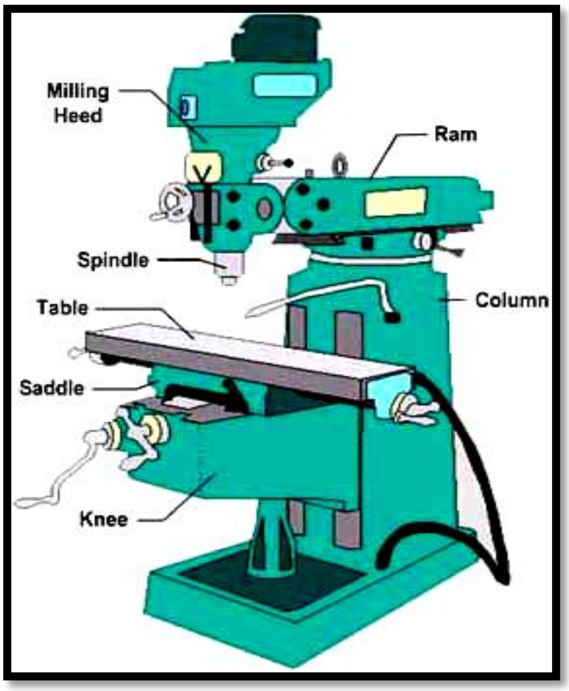


Figure 2.3: Vertical Milling Machine

Source: Krar, et al 1994

2.5.2 Horizontal Milling Machines

A horizontal mill has the same sort of x–y table, but the cutters are mounted on a horizontal arbor across the table. A majority of horizontal mills also feature a +15/-15 degree rotary table that allows milling at shallow angles. While endmills and the other types of tools available to a vertical mill may be used in a horizontal mill, their real advantage lies in arbor-mounted cutters, called side and face mills, which have a cross section rather like a circular saw, but are generally wider and smaller in diameter. Because the cutters have good support from the arbor, quite heavy cuts can be taken, enabling rapid material removal rates. Several cutters may be ganged together on the arbor to mill a complex shape of slots and planes. Special cutters can also cut grooves, bevels, radii, or indeed any section desired. These specialty cutters tend to be expensive. Simplex mills have one spindle, and duplex mills have two. It is also easier to cut gears on a horizontal mill. (S. Krar, et al 1994).

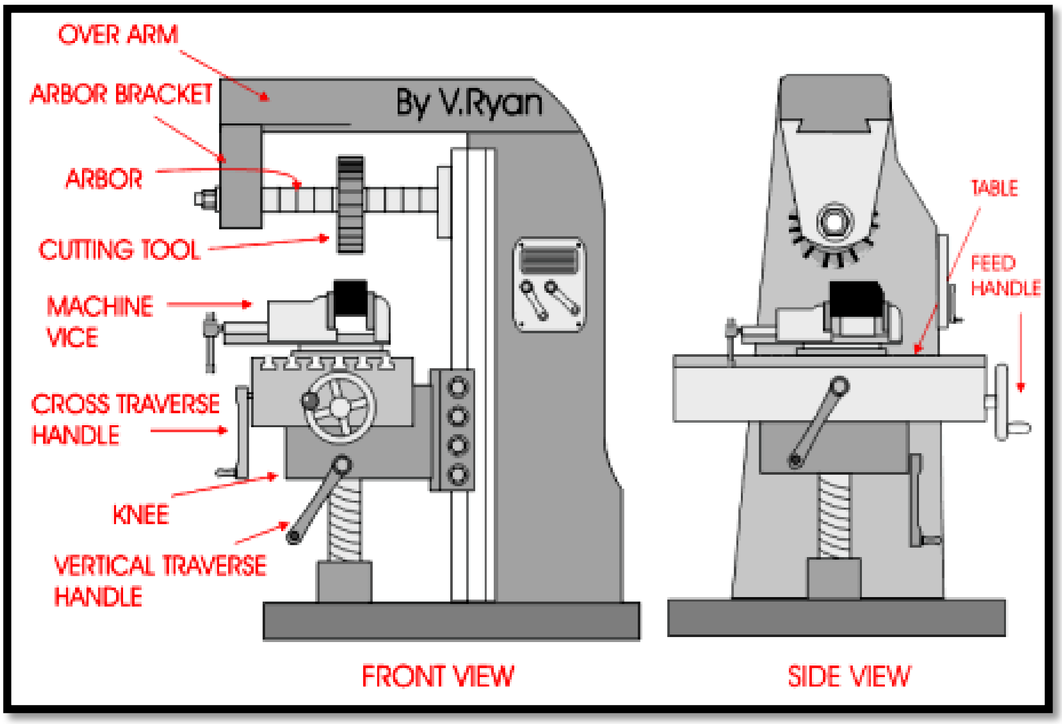


Figure 2.4: Example of horizontal milling machine

Source: Armarego et al, 1999

2.5.3 Computerized Numerical Control Machine (CNC machine)

CNC machine is a Computerized Numerical Control machine that the tool is controlled by a computer and is programmed with a machine code system that enables it to be operated with minimal supervision and with a great deal of repeatability**. CNC** mills can perform the functions of drilling and often turning. **CNC** mills are classified according to the number of axes that they posses. Axes are labelled as x and y for horizontal movement, and z for vertical movement. The same principles used in operating a manual machine are used in programming a **CNC** machine The main difference is instead of cranking handles to position a slide to a certain point, the dimension is stored in the memory of the machine control once. The control will then move the machine to these positions each time the program is run. **CNC** machine also economic to use for big size capacity for production and for special case **CNC** can be use (Armarego et al, 1999).

Figure 2.5: CNC milling machine

2.6 TOOL

In the context of machining, a cutting tool (or cutter) is any tool that is used to remove material from the workpiece by means of shear deformation. Cutting tools must be made of a material harder than the material which is to be cut, and the tool must be able to withstand the heat generated in the metal-cutting process. Also, the tool must have a specific geometry, with clearance angles designed so that the cutting edge can contact the workpiece without the rest of the tool dragging on the workpiece surface. The cutter are generally made from high speed steel (HSS) and coated carbide which means they will cut through metals such as mild steel and aluminium. There are many variables, opinions and lore to consider before selects a milling cutter (S. Krar, et al 1994).

2.6.1 Tool Material

Various cutting-tool materials with a wide range of mechanical, physical, and chemical properties have been developed over the years. The desirable tool-material characteristics are chosen based on the criteria below:

(i) Hardness and strength are important with regard to the hardness and strength of the workpiece material to be machined.
(ii) Impact strength is important in making interrupted cuts in machining, such as milling.
(iii) Melting temperature of the tool material is important versus the temperatures developed in the cutting zone.
(iv) The physical properties of thermal conductivity and coefficient of thermal expansion are important in determining the resistance of the tool materials to thermal fatigue and shock.

Tool materials generally are divided into the following categories, including:

(i) High-speed steels
(ii) Cast-cobalt alloys
(iii) Carbides
(iv) Coated tools
(v) Alumina-based ceramics
(vi) Cubic boron nitride

2.7 MACHINABILITY OF ALUMINIUM ALLOY

2.7.1 Aluminium Alloy 6061

Aluminium alloy 6061 is one of the most widely used alloys in the 600 series. This standard structural alloy, one of the most versatile of the heat treatable alloys is popular for medium to high strength requirements and has good toughness characteristic. Alloy 6061 has excellent corrosion resistance to atmospheric conditions and good corrosion resistance to sea water. This alloy also offers good finishing characteristics and responds well to anodizing. Traditional machining operations such as turning, milling, boring, tapping, sawing etc. are easily performed on aluminium and its alloys. The machines that are used can be the same as for use with steel, however optimum machining conditions such as rotational speeds and feed rates can only be achieved on machines designed for machining aluminium alloys.(Aluminum Standards and Data 2006) The specific properties of aluminum alloys must be considered is:

(i) Cutting Force

The specific cutting force needed to machine aluminum alloys is far less than is required for steel. For the same section of swarf, the force is one third of that required for aluminum than for low-carbon steel, so it follows for the same cutting force, chip removal is three times higher with aluminum alloys such as 2017A whose level of mechanical properties is on a par with that for low carbon steel.

(ii) Tooling

The geometry of tools must be specially designed for use with aluminum alloys. Edges must be very keen and cutting tool faces must be highly polished so as to remove swarf efficiently and prevent it from bonding to the tool. Cutting angles will depend on the alloys. The rake angle of the cutting edge must be greater than 6 o and can attain 12 o. The use of tools tipped with TiN or TiCN by PVD deposition only is highly advisable for machining alloys that contain no more than 7% silicon. (Angle of 15o for diamond coated carbide (CVD Diamond) tools and polycrystalline diamond (PCD) tools.) Provided tooling is designed for aluminum alloys, tool life is much longer than for machining steels, all other factors being equal.

(iii)Cutting Speeds

All wrought alloys can be machined very rapidly. With special machines (high speed spindles) the machining speed can attain (and exceed) 2 to 3000 m/min with 2000 and 7000 series alloys. Thus for a 12 mm diameter tool the cutting rate can be as high as 50,000 r.p.m. for a feed rate of 10 m/min. With very high cutting rates it is possible to obtain very thin sheet and much lighter components.

(iv)Rate of Advance and Depth of Cut

Given the low modulus of aluminum alloys, high rates of advance are not advisable, even for rough machining. The feed rate should be limited to 0.3mm per revolution. For finishing operations the rate of advance will be determined by the specified surface roughness for the finished product. The depth of cut will depend on the specified accuracy.

2.7.1 Types of chip formation

For machining aluminium alloys in dry conditions it is given the high rate of chip removal, the heat generated by the machining process is taken away with the swarf without having the time to diffuse into the metal.

(i) Discontinuous chips

This type of chip comes off as small chunks or particles. When we get this chip it may indicate of brittle work material, small rake angles and coarse feeds and low speed. When discontinuous chips are formed there is a greater possibility of tool chatter unless the tool, tool-holder and workpiece are held very rigidly due to pressure at the tool tip increasing during chip formation and then releasing suddenly as the chip shears (Kalpakjian and Schmidt 2003).

(ii) Continuous chip

The chip looks like a long ribbon with a smooth shinning surface. This chip type may indicate such as ductile work materials, large rake angles, fine feeds and high speeds. A disadvantage of continuous chips is the fact that they can become very long and become entangled with the machine or pose a safety hazard (Kalpakjian and Schmid 2003).

(iii)Continuous chips with built up edge

The type of chip that looks like a long ribbon but the surface is no longer smooth and shinning. This type of chip tends to indicate high friction between work and tool cause high temperatures that will occasionally weld the chip to the tool. This will break free but the effect is a rough cutting action

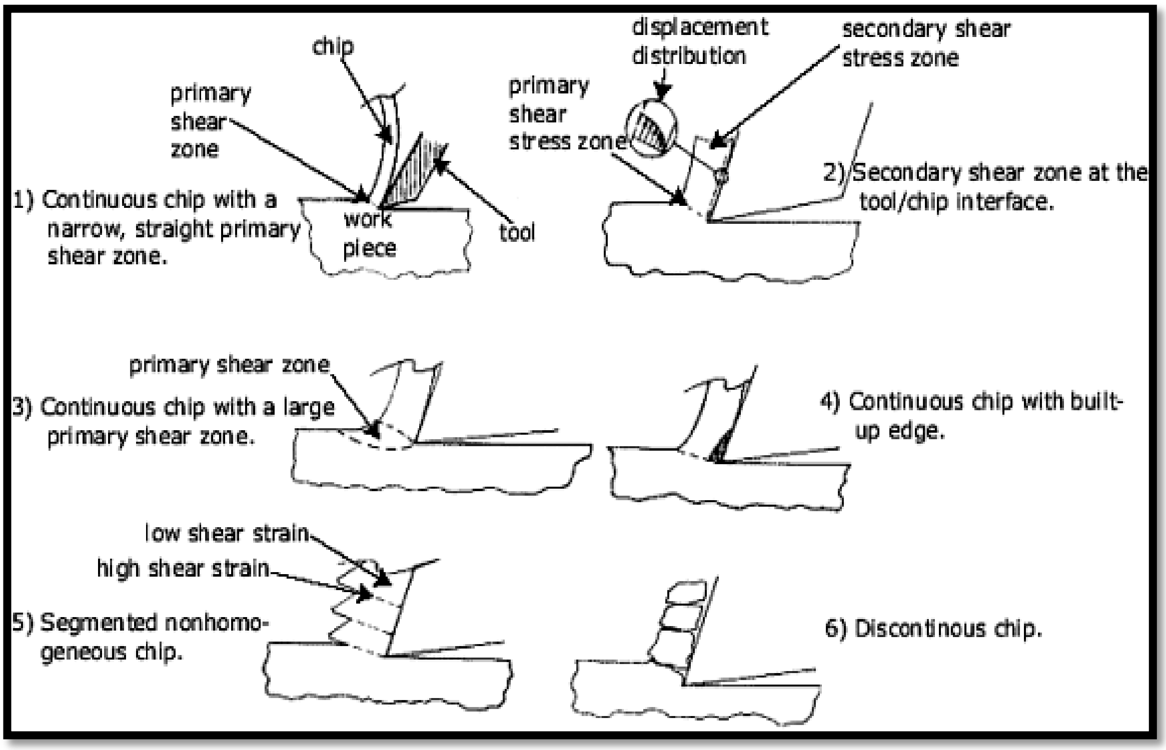


Figure 2.6: Type of chip formation

Source: Kalpakjian and Schmidt 2003

2.8 COATED CARBIDE INSERTS

Coated carbide insert is a cutting bit made of hard carbide material that has multiple cutting edges. Once a cutting edge is excessively worn, it can be indexed to another edge, or the insert can be replaced.

2.8.1 Carbide Cutting Tools

Cutting tool grades of carbides are further subdivided into two groups: cast-iron carbides and steel-grade carbides. Cast-iron carbides are specifically made for cutting cast-iron materials. These carbides are more resistant to abrasive wear, protecting the carbide cutting tool from edge wear due to the high abrasiveness of cast-iron. Steel-grade carbides are specially made to resist chattering and heat deformation that may be caused by the long chips of steel on higher cutting speeds. Whichever grade of carbide is used in a carbide cutting tool, the main carbide material used in its manufacture is tungsten carbide (WC) with a cobalt binder. Tungsten carbide is well known for its hardness and resistance to abrasive wear. Cobalt, on the other hand, is used to further toughen the tool's surface (Awopetu, 2005).

Aside from tungsten carbide and cobalt, other alloying materials are added in the manufacture of carbide cutting tools. Also commonly used in the cutting industry today is coated carbide cutting tools. The different coating materials aid the carbide cutting tool differently, although they are generally used to further toughen the cutting tool. To increase the life of carbide tools, they are sometimes coated. Four such coatings are TiN (titanium nitride), TiC (titanium carbide), Ti(C)N (titanium carbide-nitride), and TiAlN (titanium aluminum nitride). Most coatings generally increase a tool's hardness and lubricity. A coating allows the cutting edge of a tool to cleanly pass through the material without having the material gall to it. The coating also helps to decrease the temperature associated with the cutting process and increase the life of the tool (Green 1996).

2.8.2 PVD and CVD Coated Carbide Inserts

Two principal coating processes are used for indexable inserts to provide cutting edges with fundamentally different properties for machining (R. Porat and Y. Cassuto 1990)

(i) Chemical vapor deposition (CVD) which uses a higher temperature and gives thicker coatings.
(ii) Physical vapor deposition (PVD) uses a lower temperature and gives thinner coatings.

By using more than one layer of different coating materials it is possible to combine the benefits that each provides. Many insert grades have three layers of coatings to ensure good adherence between the insert substrate and coatings. Also, the laminating effect of coatings provides added strength. The coating materials are hard because they are ceramic materials, and as such they are more brittle. So, the thicker the coating, the more sensitive it is to mechanical variations. The insert substrate and the coating properties always must be balanced to suit the requirements of the application for which the grade is intended (G. Byrne et al 1995).

The CVD-coated insert typically has a thicker coating, and has a high degree of wear resistance and coating adherence. The PVD-coated insert has a thinner coating, high toughness and is more suitable for sharper cutting edges. Practically, the CVD insert is more suitable for higher cutting speeds, while the PVD insert is more suitable for lower cutting speeds. The CVD insert can cope better with heat, longer insert engagement times and larger chip thicknesses. The PVD insert copes well with instability and more demanding chip evacuation from the machining zone as well multiple as tool exits from the workpiece such as those encountered in milling.

A CVD insert typically is chosen for turning of steel and cast-iron while the PVD is typically a solution for end-milling in a machining centre with limited power. The PVD insert is well suited to the growing number of positive, sharper cutting edges required for intermittent cuts and also is used widely for solid carbide tools especially endmills and drill. But these characteristics are broad for the insert-coating types, and overlap in both turning and milling. The PVD process is the subject of intense development today because it offers great potential and can make use of more coating materials. The CVD and PVD processes generally should not be seen as competitors, rather as complimentary to each other. Both offer potentials for optimizing machining.

2.8.3 Cutting Tool Life

Tool life is one of the most important in metal cutting; however it is important economic considerations. In roughing operations, the tool material, the various tool angles, cutting speeds and feed rates are usually chosen to give an economical tool life. On the other hand, if using the low speed and federate give long tool life but it is not economical because of lower production rate. The rate of tool wear depends on tool and workpiece of material, tool shape, cutting fluid, process parameters and machine-tool characteristics. The high contact stress between the tool rake-face and chip cause severe friction at the rake face as well. There is friction between the flank and the machined surface. The result is a variety of wear patterns and scars which can be observed at the rake face and the flank face (H.Z. Li, 2002).

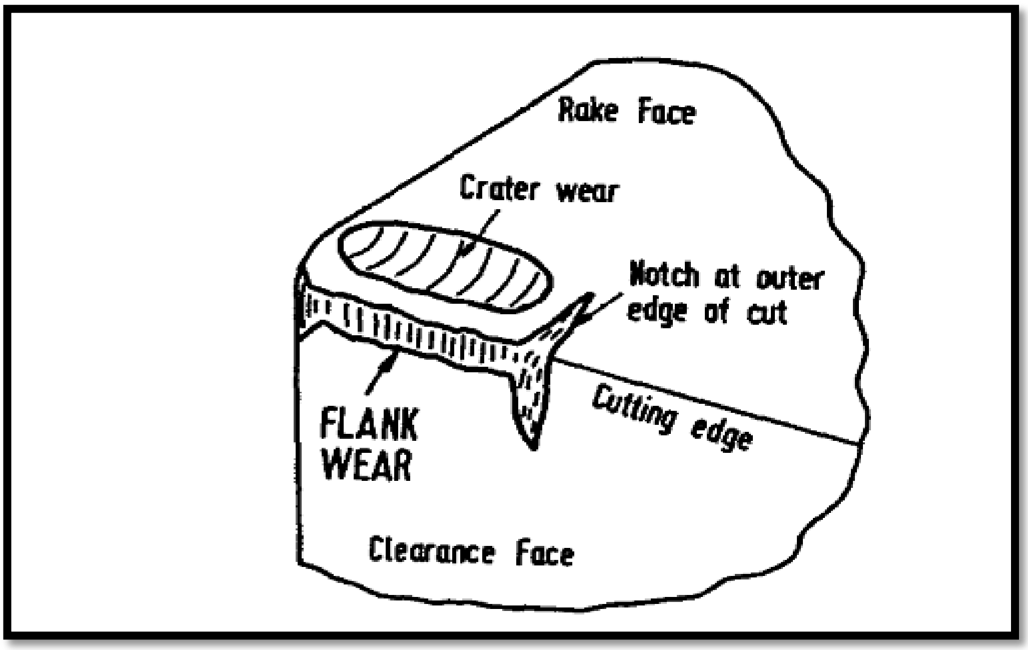


Figure 2.7: Tool wear definition

Source: Thamizhmanii 2008

Tool life can be calculated using Taylor's equation. This formula is to determine tool life and is depending upon the constant *n* and C. Where *V* is the cutting speed, *T* is the time (in minutes) that it takes to develop certain flank wear land, *n* is an exponent (that's depends on tool and workpiece materials and cutting condition) and *C* is constant.

$$V_c T^n = C \tag{2.1}$$

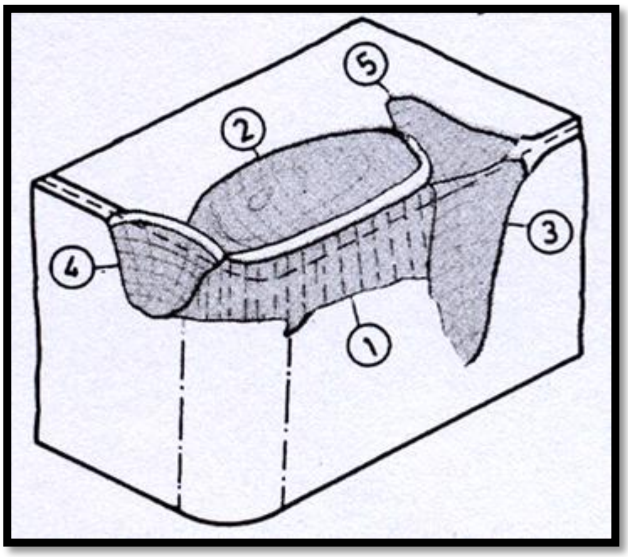
A more general form of the equation is;

$$VcT^n \times D^z f = C \tag{2.2}$$

Where x and y are determined experimentally, *D* is depth of cut, *F* is for the feed rate.

2.8.4 Types of Tool Wear

Tool wear can be categorized into several types as crater wear, notch wear, chipping, plastic deformation, ultimate failure and flank wear based on the tool wear phenomena. In practice flank wear is used to determine the tool life. Wear on the relief face is called flank wear and it occurs due to abrasive wear of the cutting tool against the machined surface. The propagation of the flank wear follows three stages, initial or preliminary wear, steady wear and severe or ultimate wear (Thamizhmanii, 2008). When the flank wear reaches critical value (severe wear) the wear rate increases, cutting force and temperature increase rapidly and the surface roughness of the machined surface decreases Figure 2.3 showed the types of tool wear that are usually occurred on an insert.



1. Flank wear
2. Crater wear
3. Notch wear
4. Oxidation wear
5. Outer chip notch

Figure 2.8: Tool geometry and wear definition

Source: M.K. Tsai 2005

2.8.5 Crater Wear

The chip flows across the rake face, resulting in severe friction between the chip and rake face, and leaves a scar on the rake face which usually parallels to the major cutting edge. The development of crater wear is closely related to the cutting temperature and pressure (G. Byrne 1991). The parameters used to measure the crater wear can be seen from Figure 2.2 Since flank wear appears in all cutting operations and directly affects the quality of machined part, monitoring of flank wear is more essential than crater wear

2.8.6 Flank Wear

Flank wear occurs on the tool flank face. It will occur in all cutting conditions. Flank wear is measured by using the average and maximum wear land size VB and VBmax. In general there are three stages of tool flank wear, and typical tool life curve is shown in Figure 2.3. The first stage is a rapid initial wear region in which the wear develops rapidly to certain level. This is in the form of micro cracking, surface oxidation and carbon loss layer, as well as micro roughness at the cutting edge in tool manufacturing. This stage is relatively short time. Second stage is progressive wear, the wear progresses linearly and comparatively longer period of time. In this stage the micro roughness around the cutting edge improves. Most of the tool useful life is in this stage. Third stage is rapid wear stage; tool wear rapidly accelerates in this stage. The wear increases to critical value VBmax, the surface quality of the machined surface degrades, cutting force and temperature increases severely. It is usually recommended that the tool be replaced before this stage.

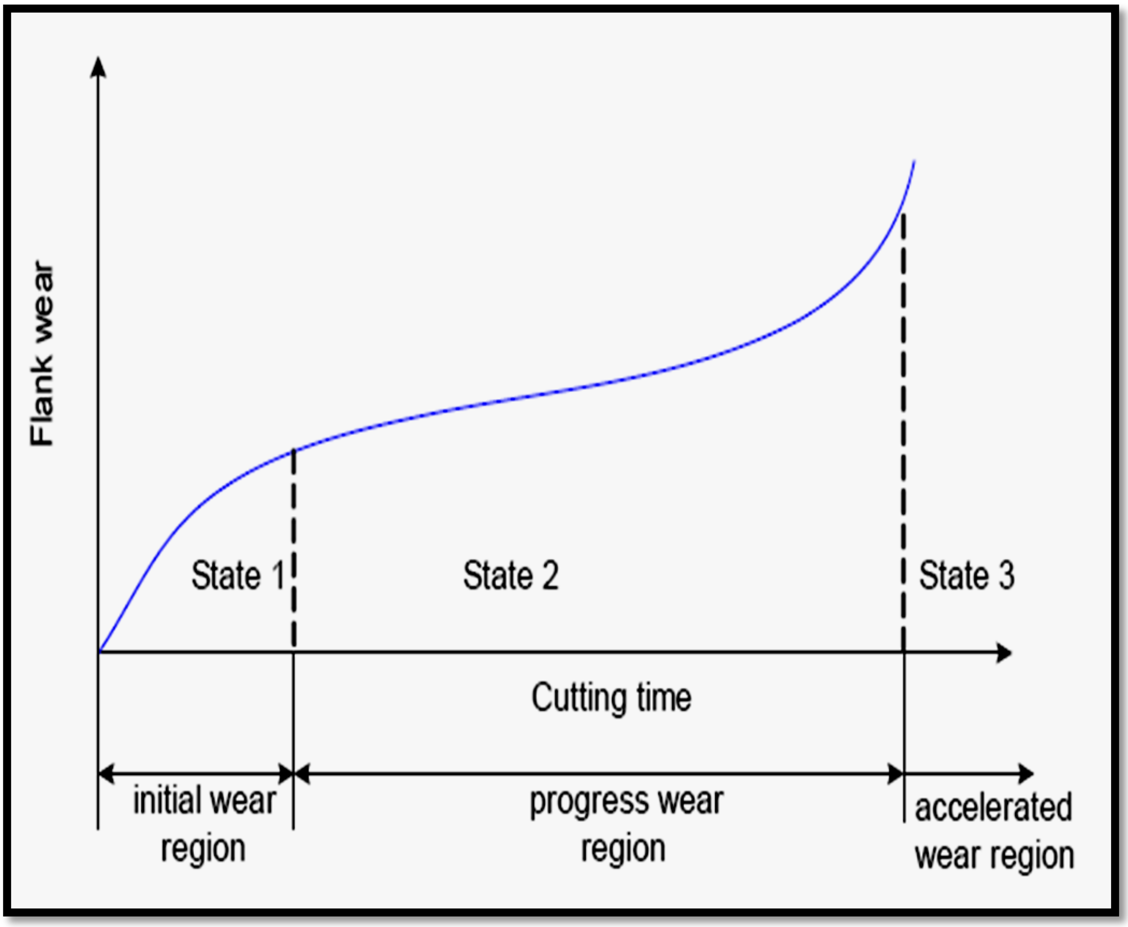


Figure 2.9: Three stage of tool flank wear

Source: T. Tamizharasan 2005

2.9 PREVIOUS RESEARCH

H.H Hassan, J.A Ghani and L.A Choudhry (2003) used Taguchi optimization methodology, which is applied to optimize cutting parameters in end milling when machining hardened steel AISI H13 with TiN coated P10 carbide insert parameters insert parameters evaluated is cutting speed, feed rate and depth of cut. Using Taguchi method for design of experiment (DOE), other significant effects such as the interaction among milling parameters are also investigated. The paper shows that the Taguchi method is suitable to solve the stated problem with minimum number of trials as compared with a full factorial design.

H.Z. Li, H. Zeng, X.Q. Chen (2006) study of end milling Inconel 718 using coated carbide inserts found that that significant flank wear was the predominant failure mode affecting tool performance and tool life. The tool flank wear propagation in the up milling operations was more rapid than that in the down milling operations under dry conditions. This work does the optimization on tool life from all the machining operation required to produce the product. The parameter considered is axial and radial depth of cut, feed rate and cutting speed. These values have been determined based on optimum machining parameters in comparison with those resulting from handbook recommendations.

K. Kadirgama, K. Ahmed N. Abd-Alla, B. Mohammad, M. M. Noor (2007) used Particle Swarm Optimization (PSO) for this optimization. This work has presented a new approach to optimizing the cutting condition in end milling (feed rate and speed) subject to a near to comprehensive set of constraints when machining of P20 tool steels with end-milling. . The model developed were used to calculate the tool life based on Response Surface Method (RSM).It was found that the feedrate, cutting speed, axial depth and radial depth played a major role in determining the tool life. On the other hand, the tool life increases with a reduction in cutting speed and feedrate. In addition, the second order model proves that there is no interaction among the variables.

M. Alauddin a, M.A. El Baradie b-*, M.S.J. Hashmi (1996), studied the tool life prediction in end milling on cold-rolled steel using cobalt-alloyed HSS found that the speed- and feed-effect are significant in both the first- and second-order models, whilst while the effect of the axial depth of cut is significant in the second-order model only. In the first-order model, the effect of axial depth of cut (i.e. narrow range) on tool life is not so significant. An increase in the speed, the feed, and the axial depth of cut decrease the tool life

S.K. Choudhury, I.V.K. Appa Rao (2001) found that when machining carbon steel, an optimisation technique has been used to machine under optimal parameters of speed and feed for a given MRR. The basic idea was to reduce the slope of the flank wear-time curve, so that tool life could be improved to the maximum possible extent. Also the increased feed will increase the chip tool contact length. This caused better distribution of heat, reduced both flank and crater wear rates and increased the tool life.

Godfrey C. Onwbolu (2005), propose a new optimization technique based on Tribes for determination of cutting parameters in multi-pass milling operations such as plain milling and face milling by simultaneously considering multi-pass rough machining and finishing machining. The optimum milling parameters are determined by minimizing the maximum production rate criterion subject to several practical technological constraints. The cutting model formulated is a nonlinear, constrained programming problem. Experimental result shows that the purposed Tribes-based approach is both effective and efficient.

Turnad L.Ginta, A.K.M Nurul Amin H.C.D Mohd Radzi (2009) presents an approach to establish models for tool life in end milling of titanium alloy Ti–6Al– 4V using uncoated carbide inserts under dry conditions and found that the tool life models show that the cutting speed is the main factors on the tool life, followed by the feed and axial depth of cut. Also it is found that an increase of cutting speed, axial depth ofcut and feed by 100%, will lead to reduction of tool life by 70%, 27%, and 37%, respectively.

G. Prabhaharan, N. Baskar, P. Asokan and R. Saravanan (2005), outlines the development of an optimization strategy to determined the optimum cutting parameters for multi-tool milling operations like face milling, corner milling, pocket milling and slot milling. The develop strategy based on the maximum profit rate criterion and incorporates five technological constraints. In this paper, optimization procedures based on the genetic algorithm, hill climbing algorithm and memetic milling operation. An objective function based on maximum profit in milling operation has been developed. Results obtained are used in NC machine. The results are compared and analyzed with method feasible directions and handbook recommendations.

G.H. Qin, M. Wan, W.H. Zhang and G. Tan (2007), present the procedure integrates the cutting force module consisting of calculating the instantaneous uncut chip thickness (IUCT), calibrating the instantaneous cutting force coefficients (ICFC) and the cutting process module consisting of calculating the cutting configuration and static form errors. It used to check the process reasonability and to optimize the process parameters for high precision milling. Comparisons of the cutting forces and form errors obtained numerically and experimentally confirm the validity of the purposed simulation procedure.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter describes experimental work and methodology of the project, with focus on the tool wear of coated carbide inserts during machining Aluminium alloy, 6061. The following sections describe the experiment detail and type of equipment used. Relevant data collection is done in order for further research analysis in subsequent chapter.

3.2 PROJECT METHODOLOGY

Methodology flow chart is representation of the sequence of the project. A detail explanation on method of this experiment is described in the next topic. Firstly literature review was been study with the fields that regards to this project. Then, the process begins with modelling and defines the optimum of tool life. In this experiment, the constant value of cutting speed from 100 – 180 m/min; the depth of cut remain constant at 2 mm and the feed rate used are 0.1 – 0.2 mm/tooth Cutting parameters, types of tool and workpiece material also included. Tool wear was measure using image analyzer.

3.3 LITERATURE STUDY

The project starts with literature review and research about the title. This consist a review of the milling machine and milling process, problem and the objective project, the previous method uses and related of tool wear to the problem. These tasks have been done through research on the internet, books and other relevant sources. Information about properties of aluminium alloy, coated carbide inserts and literature review on tool wear.

After gathering all the relevant information, the project proceeds with analysis the problem and the method were used. In this step, from the knowledge gather from the review is use to make a compared table to identified all the method used to optimize milling parameter and the top parameters were used. Finally, complete the report and submit on the submission date.

3.4 DESIGN OF EXPERIMENT (DOE)

For this project, MINITAB software is used to generate the design of experiment. Minitab is statistical analysis software. It can be used for learning about statistics as well as statistical research. Statistical analysis computer applications have the advantage of being accurate, reliable, and generally faster than computing statistics and drawing graphs by hand. Minitab is relatively easy to use once you know a few fundamentals. (Meyer 2004).

To generate the parameters used for experiment, 3 different types of independent variables that are cutting speed, depth of cut and feed rate, each with 3 different levels of values as showed in Table 3.1 is key in into the software. Then from the software, by selecting response surface methodology (RSM) with a Box-Behkin method design of experiment, 15 different sets of experiments, each with different level of values will be generated as showed in Table 3.2 and all the experiment sets will be mixed randomly to reduce the random error occurred. In this experiment there is no any repetition experiment performed.

Table 3.1: Parameters used for experiments

Cutting Speed, Vc (m/min)	Feed Rate, f (mm/rev)	Depth of Cut, (mm)
100	0.05	1
140	0.10	1.5
180	0.15	2

Table 3.2: DOE table generated by MINITAB software

No of exp.	C/Speed (m/min)	Feed(mm/tooth)	Depth of Cut(mm)
1	140	0.2	1.5
2	140	0.2	1
3	140	0.15	1.5
4	180	0.15	1
5	180	0.15	2
6	180	0.2	1.5
7	180	0.1	1.5
8	140	0.15	1.5
9	140	0.2	2
10	140	0.1	2
11	140	0.15	1
12	100	0.2	1.5
13	100	0.15	1
14	100	0.15	2
15	100	0.1	1.5

3.5 EXPERIMENTAL SETUP

3.5.1 Aluminium alloys 6061

The workpiece material used in the machining test was Aluminium alloys 6061. The workpieces were cut off from using Everising band saw, and their surfaces were prepared through face milling to get rid of the original skin layer containing hard particles. Aluminium alloy 6061 is a precipitation hardening aluminium alloy, containing magnesium and silicon as its major alloying elements. It has good mechanical properties and exhibits good weldability. It is one of the most common alloys of aluminium for general purpose use. The mechanical properties for the workpiece material are shown in Table 3.3

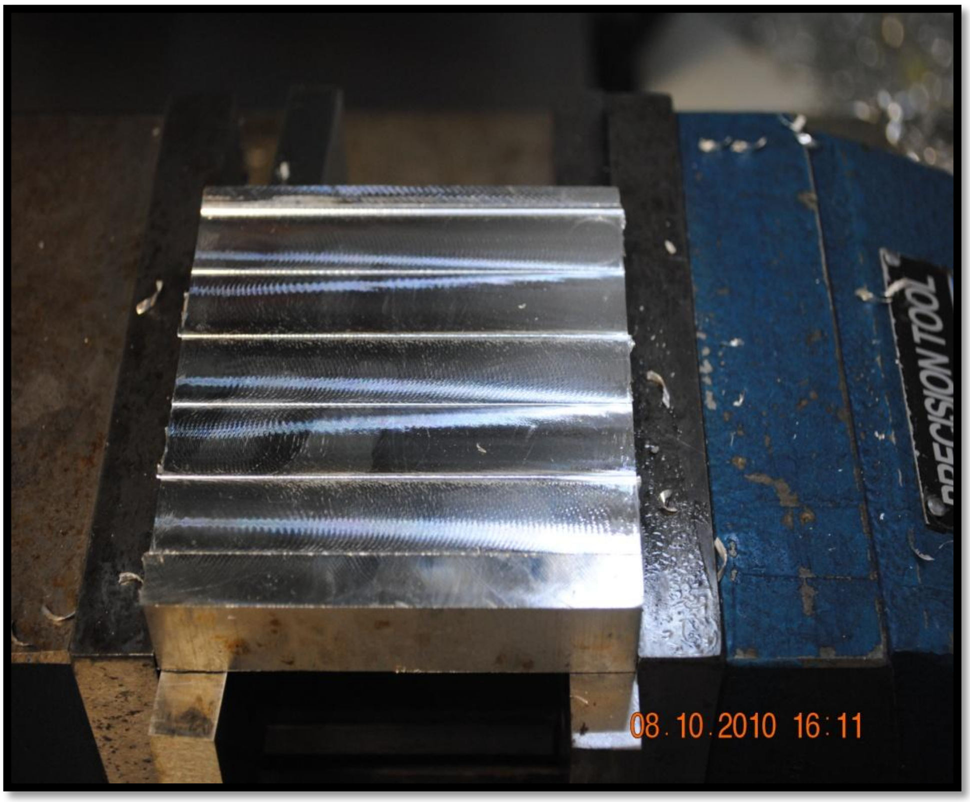


Figure 3.1: Aluminium specimen used for the experiment

Table 3.3: Mechanical Properties of Aluminum Alloy (6061)

Workpiece Material	Aluminium Alloy 6061
Tensile Strength (Mpa)	310
Tensile Yield Strength (Mpa)	276
Modulus of Elasticity (Gpa)	68.9
Specific Heat (J/g-°C)	0.896

Source: Source: Structural Alloys Handbook 1996

Table 3.4: Chemical composition of Al 6061

Element	Mg	Fe	Si	Cu	Mn	V	Ti	Al
Weight %	1.08	0.17	0.63	0.32	0.52	0.01	0.02	Remainder

Source: Structural Alloys Handbook 1996

3.5.2 Cutting Tool

The cutting tool used in this study is a 0º lead – positive end milling cutter of 31.75 mm diameter. The end mill can be equipped with two square inserts whose all four edges can be used for cutting. The cutting tool used in the machining test was a SECO SEMX1204AFTN-M15 end milling cutter with a F40M coated carbide insert. The tool diameter was 16 mm. The insert had a square shape, back rake angle of 0º, clearance angle of 11º, and nose radius of 0.794 mm and had chip breaker. The inserts are coated with a single layer of TiN.

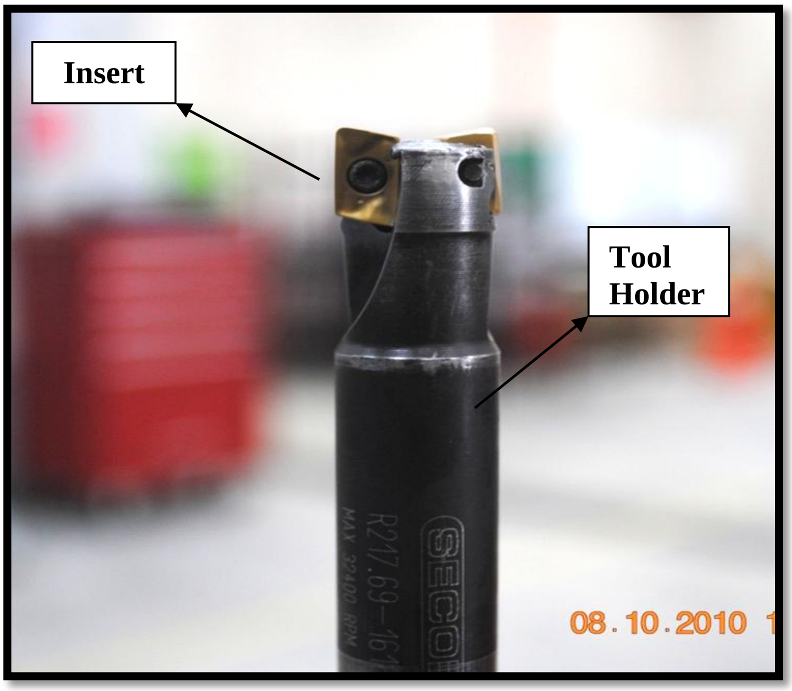


Figure 3.2: Tool Holder and Insert

3.5.3 Machine Tool

The machine tool used in the cutting test was a three-axis vertical milling machine tool (FANUC Robodrill T14iEe) with a PC-based NC controller. The machine table could be moved in Cartesian coordinates in x-, y-, and z-direction.

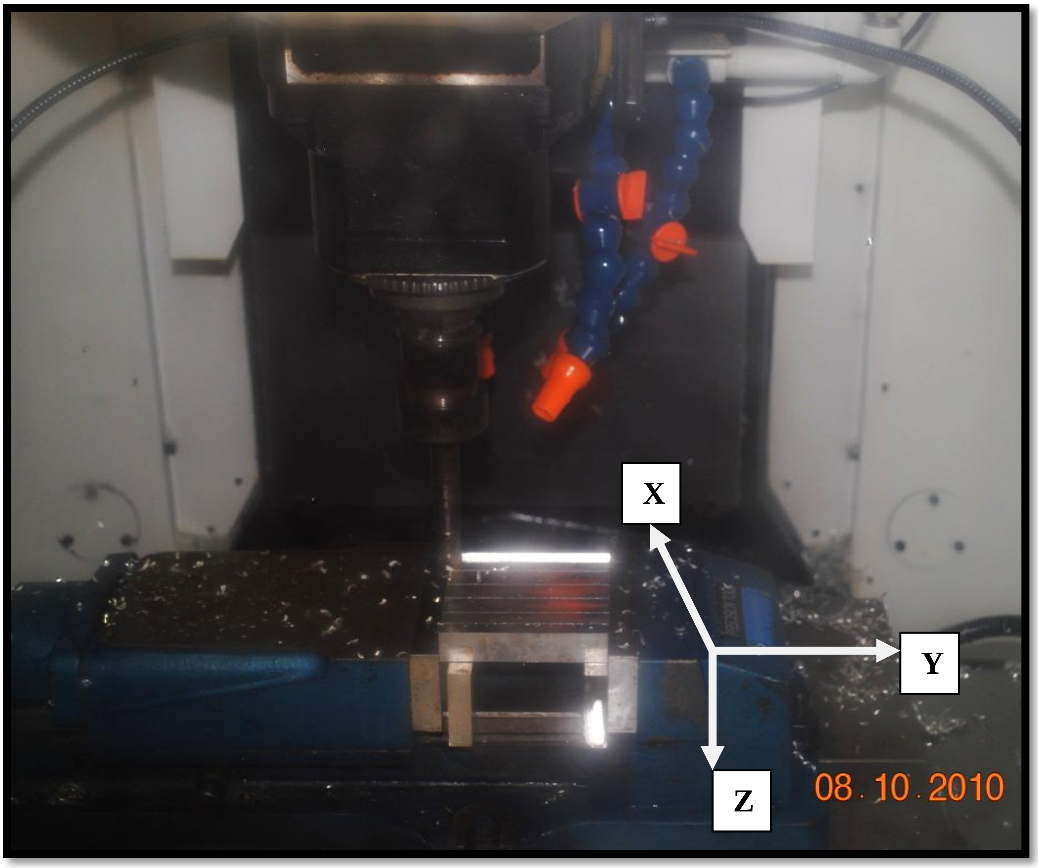


Figure 3.3: Experimental setup

3.6 EXPERIMENTAL PROCEDURE

The machining tests were carried out in types of end milling operations. The axial depth of cut *d*a was 2 mm. The feed per tooth ft was 0.2 mm. The cutting speeds were 180 m/min (spindle speed n was 3600 rpm) and 100 m/min (spindle speed was 2000 rpm). The feed direction of the workpiece was along the negative x-axis as shown in Fig. 1, and the workpiece length in the feed direction L was 100 mm. Dry cutting was used for the experiment. For the experiment, two inserts were used to cut the workpiece in succession, and the flank wear of the inserts was measured after each cutting pass using. Depending on the cutting conditions and wear rate, machining was stopped at various interval of cutting length from 50 mm to 100 mm to record the wear of the inserts and the wear was measured under IM 1700 Series Image Analyzer microscopy system.

The relationship between the cutting speed and the rotational spindle speed can be expressed as follows in Eq. (3.1):

$$\boldsymbol{N = \frac{1000V}{\pi D}} \qquad \text{(eq - 3.1)}$$

Where:

N = Spindle speed, rpm;
V = Cutting speed, m/min; and
D = cutter diameter in millimeters.

The feed rate, which is the milling machine table feed rate, is defined as follows:

$$\boldsymbol{f_m = f_t n_t N} \qquad \text{(eq - 3.2)}$$

Where:

f_m = Table feed rate, mm/min;
f_t = Feed per tooth, mm/tooth;
n_t = Number of teeth employed in the milling cutter; and
N = Spindle speed, rpm.

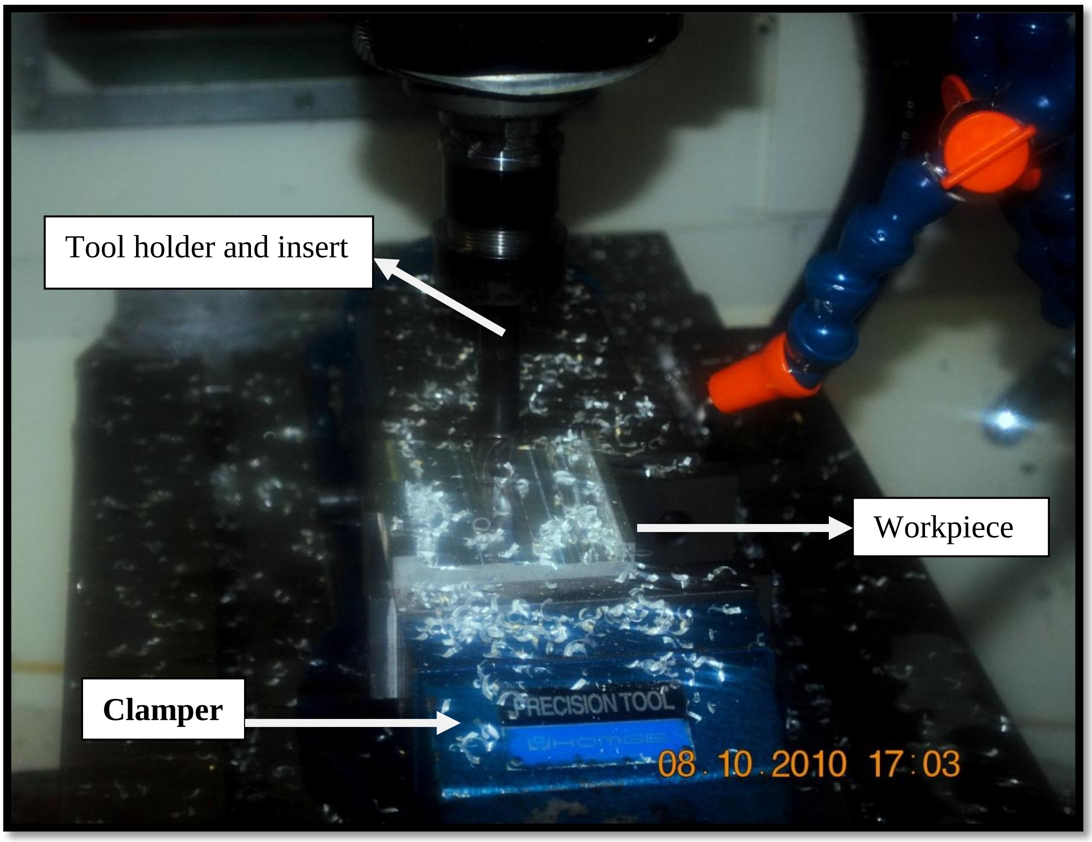


Figure 3.4: Clamper used to hold the specimen

3.7 INVESTIGATION OF TOOL WEAR

After each time of machining, the inserts will be taken out from the tool holder and the tool wear of the inserts is observed by using the optical microscope with IM 7000 series Image Analyzer as showed in Figure 3.8. From the image analyzer, the image of the flank wear from each set of experiments will be captured by using the camera that is attached with the optical microscope and connected with the Image Analyzer. It is not comparable to a fully fledged image analyzer such as scanning electron microscope (SEM) but it is able to stand its ground on beginner researcher level. After the image of flank wear from each set of experiment are captured, the size of flank wear measured by using the measuring features that is provided in the Image Analyzer under the magnification of the optical microscope. After each measurement is taken, the flank and crater wear from each set of experiment are recorded.

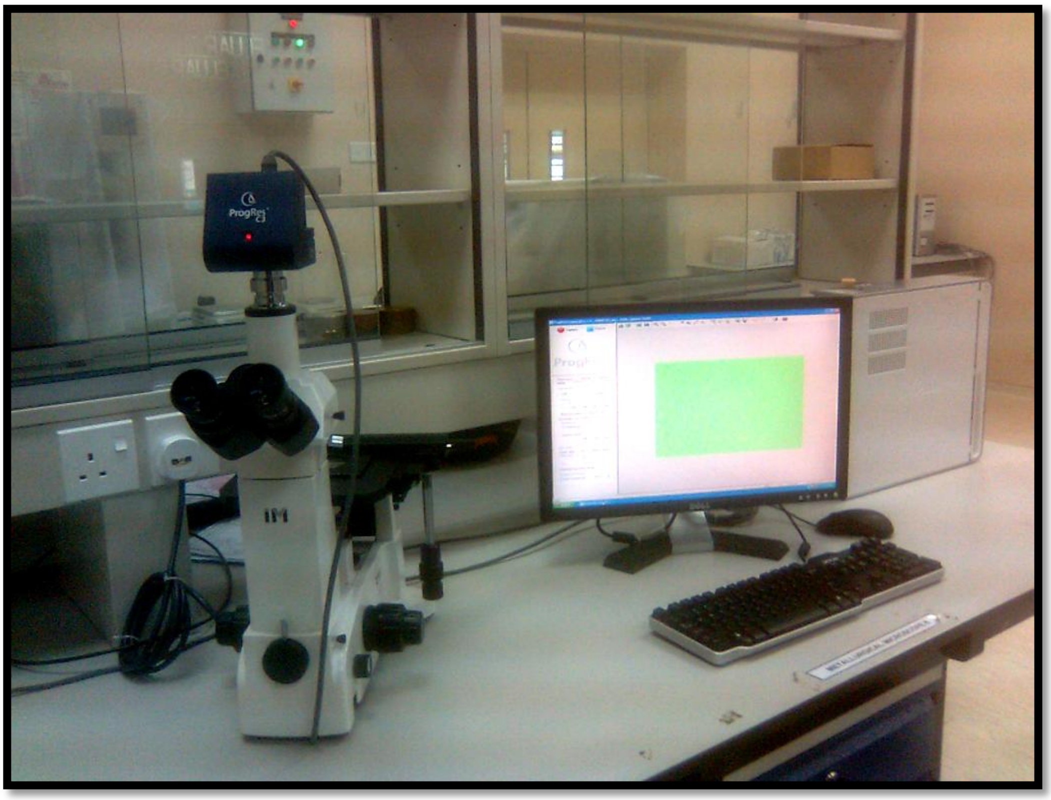


Figure 3.5: IM 7000 series Image Analyzer

3.8 DATA COMPARISON AND DOCUMENTATION

After all the machining done and flank wear of the coated carbide insert is observed, analysis of the tool wear taken place until the final machining. Based on ISO standards, a maximum of 0.3 mm of uniform flank wear (Vb) is permitted for useful tool life of coated carbide. Due to the tool holder damage during the experiment, a maximum uniform of flank wear is considered as 0.13 mm. The tool lives were read off from the graphs of flank wear against time at each cutting speed.

3.9 SUMMARY

Milling process of aluminum alloy has been done under a variables parameters and image analyzer is used to measure tool wear. The results obtained are following from the analysis will be discussed in the next chapter.

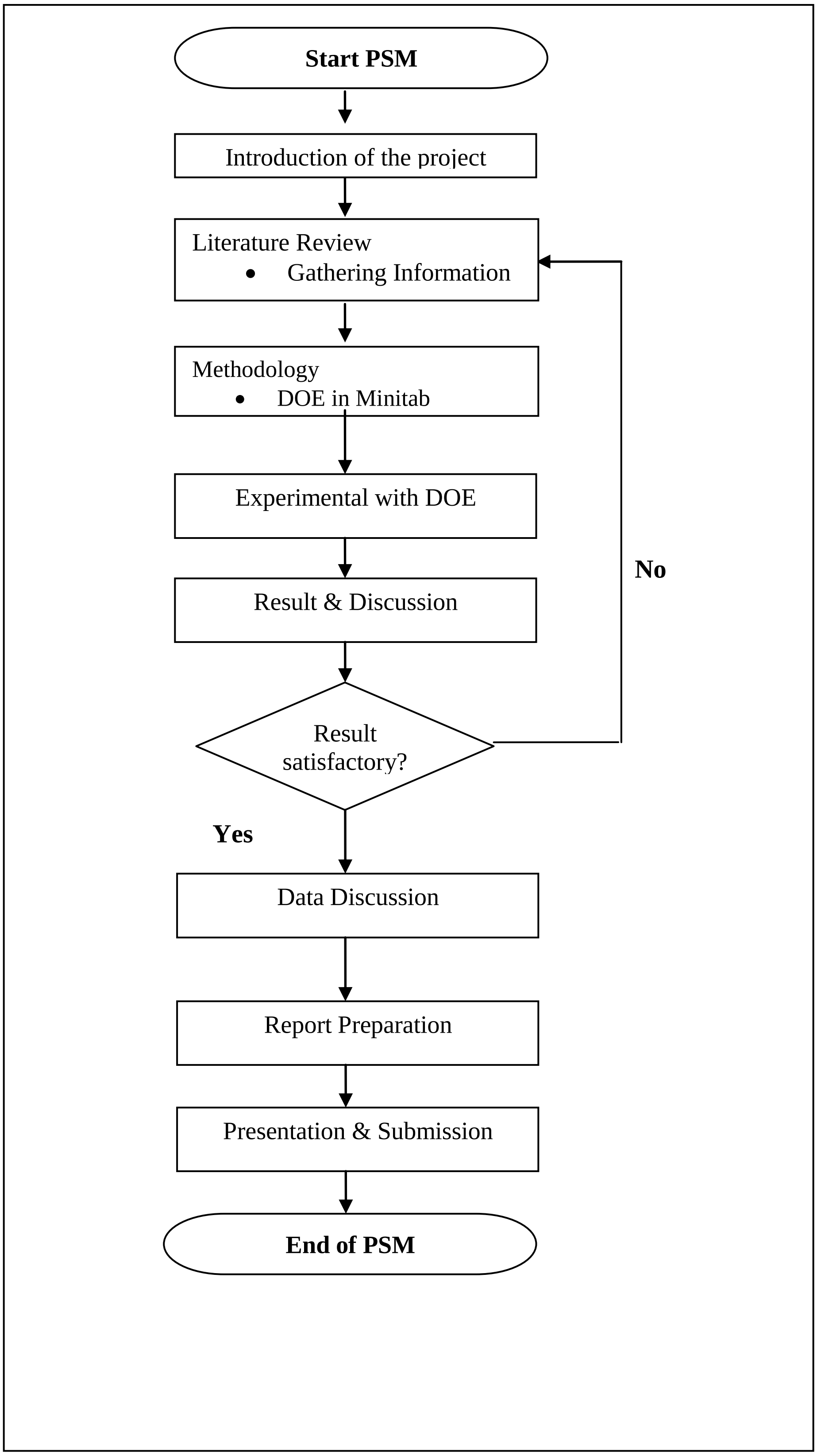


Figure 3.6: Summary of PSM 1 and 2 Methodology

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

Chapter 4 is generally discuss the results obtained throughout the experimental research analysis on the tool flank wear (μm) of the coated carbide TiN single layer insert found after a period of machining process. After that, the tool wear curves are plotted by using Excel to determine the orientation of the tool wear curves.

4.2 FLANK WEAR

Figure 4.1 shows the rake face and flank face of the new insert (unused) as captured by using optical microscope. The magnification used at the optical lens was 50 times. The transformed magnification was adjusted by the integrated image analyzer. When it was transferred to the image analyzer environment, the rake face and flank face were focused on the major cutting edge where flank wear would take place as the machining was progressed.

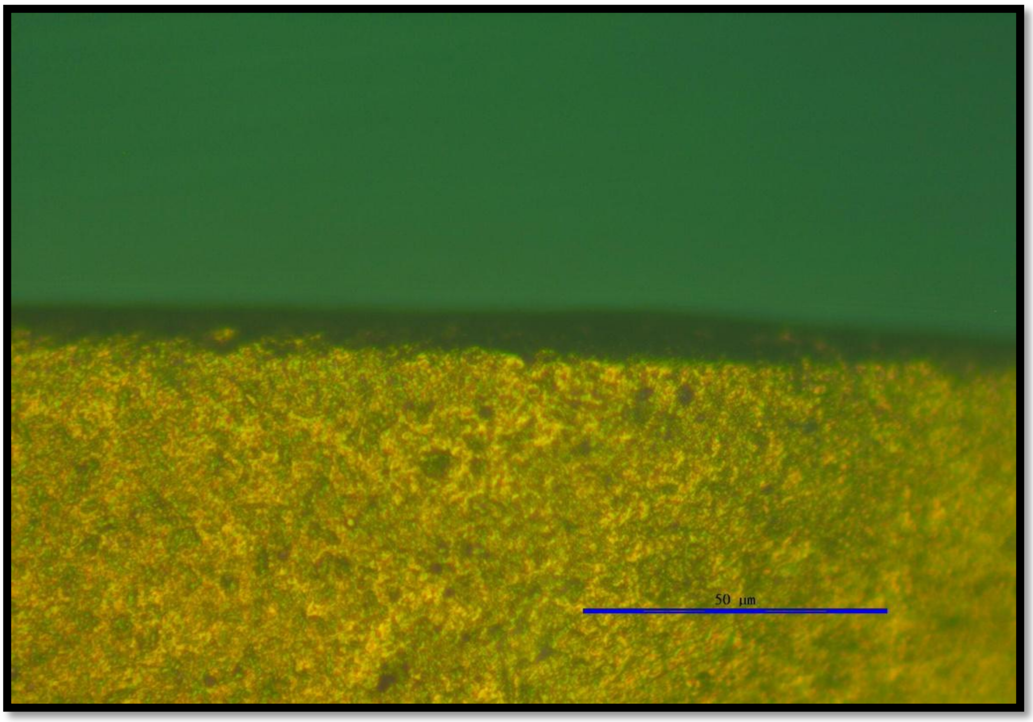


Figure 4.1: New Flank face of coated carbide

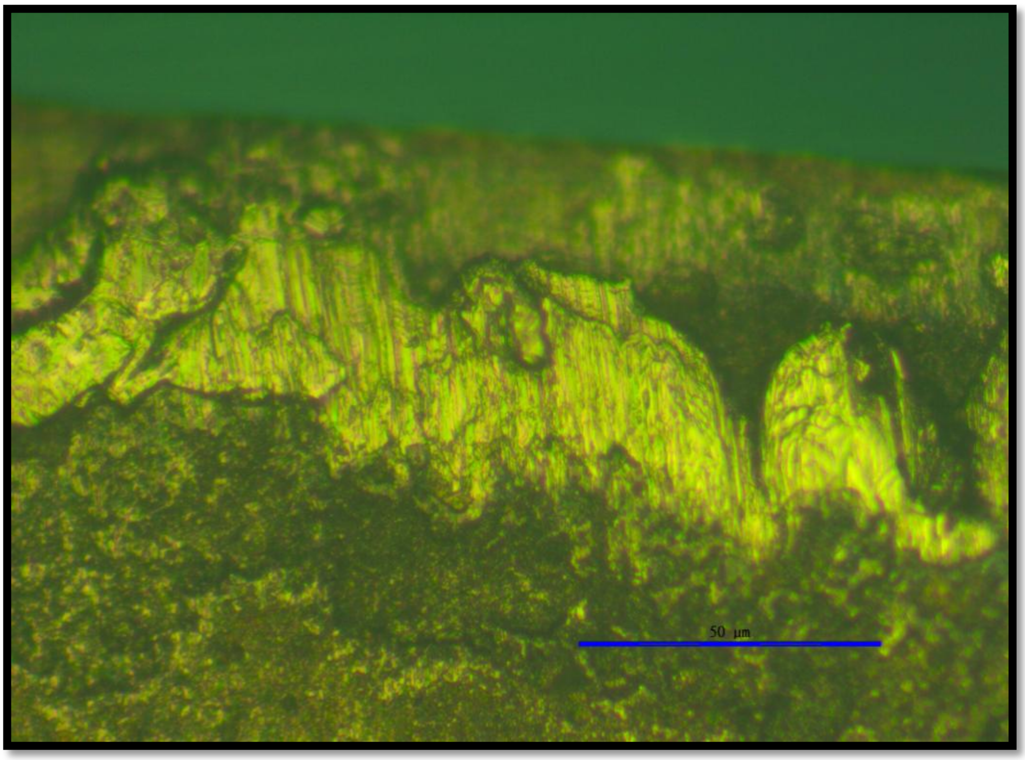


Figure 4.2: Flank wear at experiment (100 m/min, 0.1mm/rev, 0.1mm/tooth)

Table 4.1: Conditions of cutting experiments according to Box-Behnken design.

No exp.	Cutting Speed(m/min)	Feed(mm/tooth)	Depth of Cut(mm)	Rpm	Feed rate(mm/min)
1	140	0.2	1.5	2800	1120
2	140	0.2	1	2800	1120
3	140	0.15	1.5	2800	840
4	180	0.15	1	3600	1080
5	180	0.15	2	3600	1080
6	180	0.2	1.5	3600	1440
7	180	0.1	1.5	3600	720
8	140	0.15	1.5	2800	840
9	140	0.2	2	2800	1120
10	140	0.1	2	2800	560
11	140	0.15	1	2800	840
12	100	0.1	1	2000	800
13	100	0.2	1	2000	600
14	100	0.15	2	2000	600
15	100	0.1	1.5	2000	400

In this experiment, a total of 15 sets of experiments are being performed. Each set of experiment has the different level of parameters of variables because the design of experiment (DOE) of this project is created by using full factorial design and the DOE is generated by using MINITAB software. Full factorial design was used because this DOE design is sufficient enough to determine the rate of tool wear and to decide the variable that will affect the tool wear most. (Behnken 1960)

There is no any repetition experiment performed since the full factorial design is sufficient enough to determine the rate of tool wear and to decide the variable that will affect the tool wear most. In addition, the material available and time allowed for performing the experiment is not enough to perform repetition experiments.

4.3 ANALYSIS OF TOOL WEAR

The flank wear occurred at different cutting speed and depth of cut was compared and recorded. By using IM 1700 Image Analyzer, tool wear analysis is done to observe wear occurrences from machining experimentation. Figure 4.1 to 4.2 for both tool wear respectively. In this study, main focus was on flank wear by the factor based on various studies done for end milling process of Aluminum alloy 6061 revealed the tool wear was mainly restricted to flank wear.

According to Choudhury (1995) the effect of feed on tool life is much more pronounced than the effect of speed. Alauddin et al. (1997) found that an increased in the speed, the feed, and the axial depth of cut decreased the tool life. Based on these statement, the occurrence of tool wear had been analyze and measure in order to investigate the tool life in end milling when machining the aluminum alloy 6061.

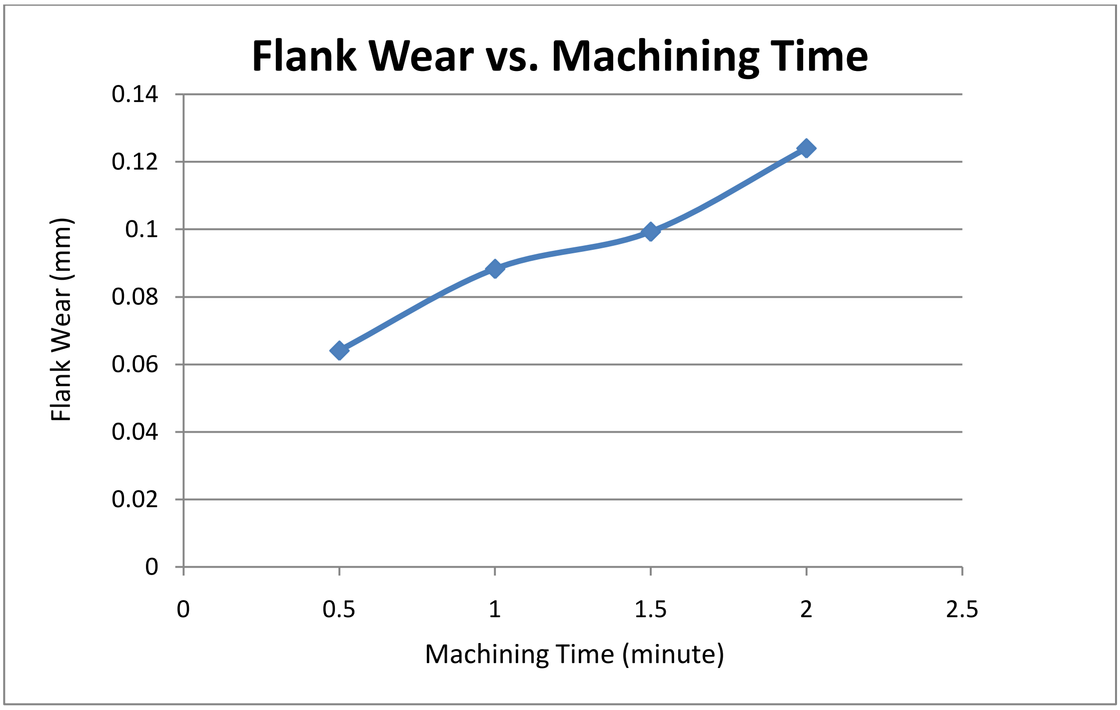


Figure 4.3: Graph of flank wear vs. machining time (Vc=100m/min, f=1.5mm/tooth)

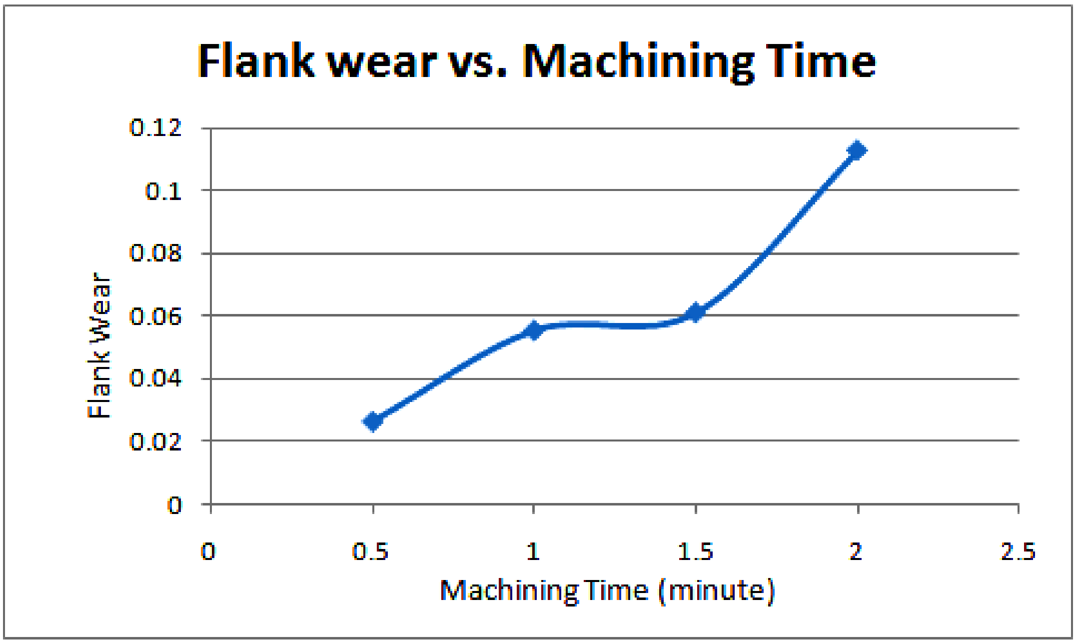


Figure 4.4: Graph of flank wear vs. machining time (Vc=140m/min, f=1.5mm/tooth)

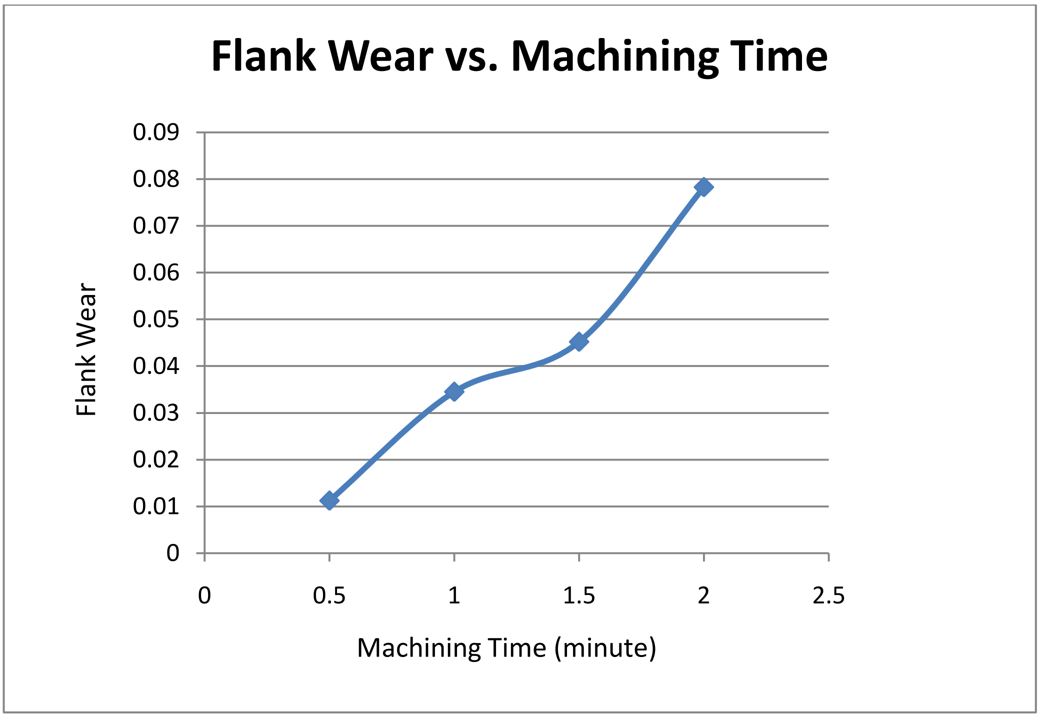


Figure 4.5: Graph of flank wear vs machining time (Vc=180m/min, f=1.5mm/tooth)

Figure 4.3 to 4.5 shows that for dry cutting operations (i.e. without coolant), at a cutting speed of 100 m/min, the flank wear values of the higher cutting speed inserts were initially lower than that of the lower cutting speed inserts. In fact, as machining time increased for the higher speeds in this study, the flank wear development of the coated carbide inserts are statistically significant in decreasing the tool wear.

4.4 DEVELOP OF MATHEMATICAL MODEL

The first-order model was developed to obtain the interaction between the variables. The model equation is:

$$Y = 0.229438 - 7.62500exp - (0.4)X_1 - 0.470497X_2 + 0.00946878X_3 \quad (4.1)$$

The adequacy of the first order model was verified using the analysis of variance (ANOVA). At a level of confidence of 95%, the model was checked for its adequacy. As it is shown in Table 4.2, indicates that the model is adequate since the P values of the lack-of-fit are not significant and F- statistics is 0.4. This implies that the model could fit and it is adequate.

Table 4.2: Adequacy of the model

Source	**DF**	**Seq SS**	**Adj SS**	**Adj MS**	F	P
Regression	3	0.012124	0.012124	0.004041	25.14	0.000
Linear	3	0.009412	0.010454	0.003485	25.14	0.000
Residual Error	5	0.001768	0.001768	0.000161		
Lack-of-Fit	4	0.001412	0.001412	0.001432	0.40	0.857
Pure Error	1	0.000356	0.000356	0.000356		
Total	14	0.013892				

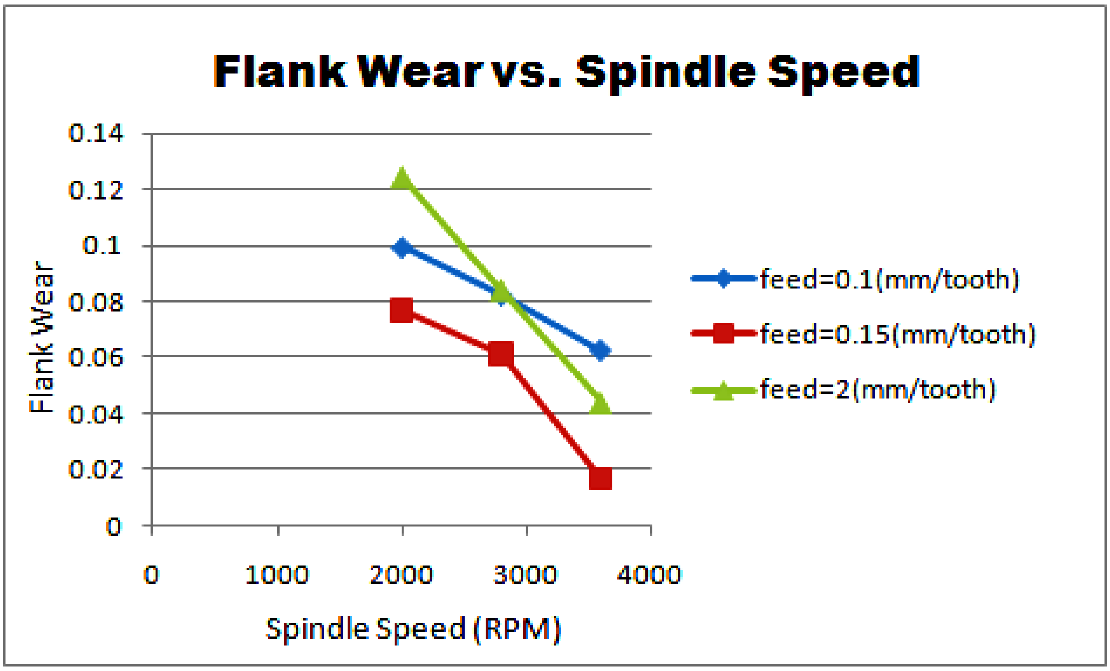


Figure 4.6: Graph Flank Wear vs. Spindle Speed (depth of cut=1.5mm)

From Fig 4.6 it is understandable that increase in spindle speed reduces the tool wear. Increase in spindle speed results in reduced cutting time, which in turn reduces the propagation of flank wear.

4.5 INTERACTION EFFECT OF VARIABLES

Strong interaction was observed between various process parameters for tool wear. The most significant interaction effect was found between cutting speeds and feed rate; cutting speed and axial depth of cut. The contour graph between these most significant process parameter interactions are shown in Figure 4.7(a) and (b). The following conclusion can be made from these interaction plots.

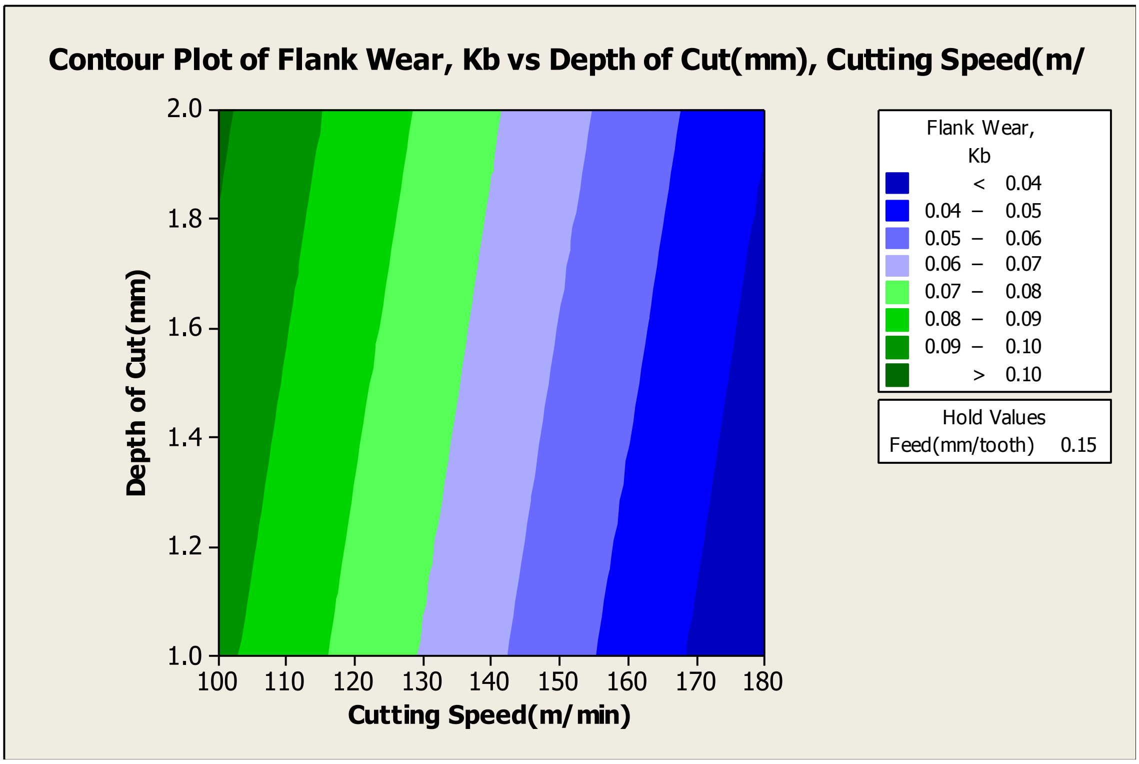


Figure 4.7(a): Contour graph of interaction effect of cutting speed and d.o.c

Fig 4.7(a) shows the interaction effect of cutting speed and axial depth of cut on tool wear. From the figure it is clear that tool wear decreases with increase in cutting speed for the axial depth of cut. Increase in axial depth of cut makes end mill cutter and work piece to be stable which resulted in reduced chatter vibration. These reductions in vibration in turn cause the propagation of flank wear within the steady region.

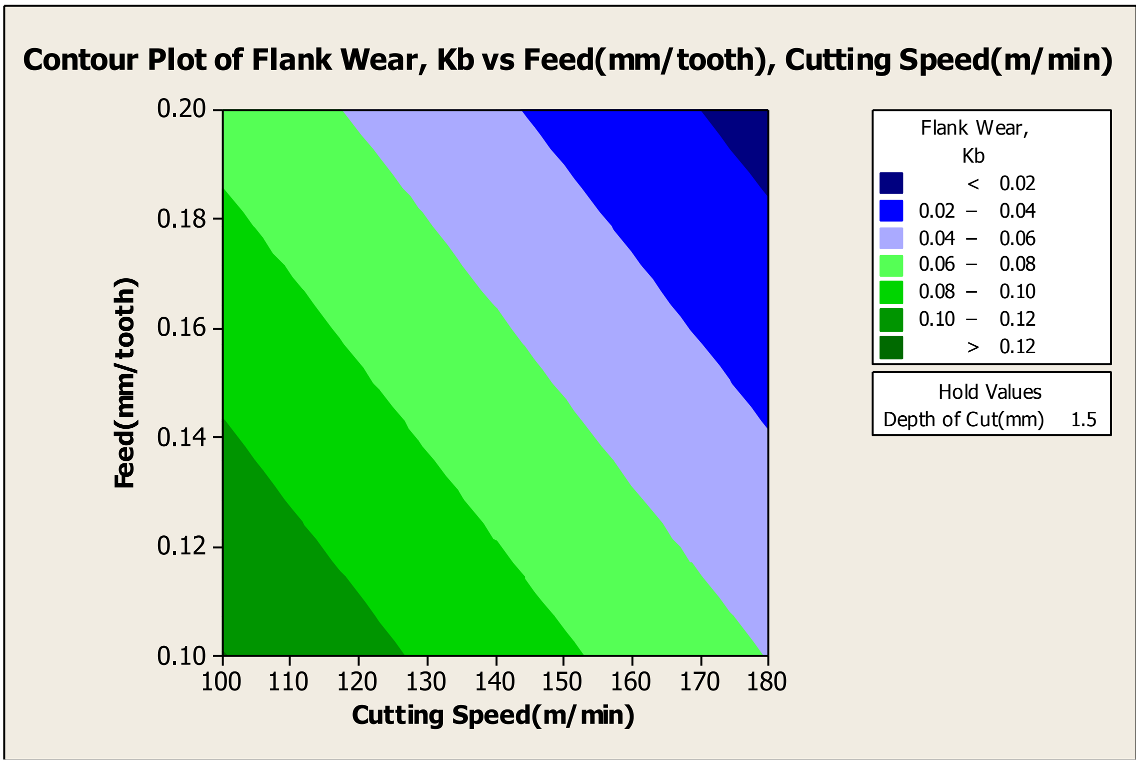


Figure 4.7(b): Contour graph of interaction effect of cutting speed and federate.

Fig 4.7(b) shows the interaction effect of cutting speed and feed rate on tool wear. From the figure it is understandable that increase in spindle speed reduces the tool wear. Increase in spindle speed results in reduced cutting time, which in turn reduces the propagation of flank wear

The results are agreeable as these curves proved that cutting speed has the most significant effects on the tool wear since the gradient of the slope in the graphs are remarkably high followed by feed and radial depth of cut.

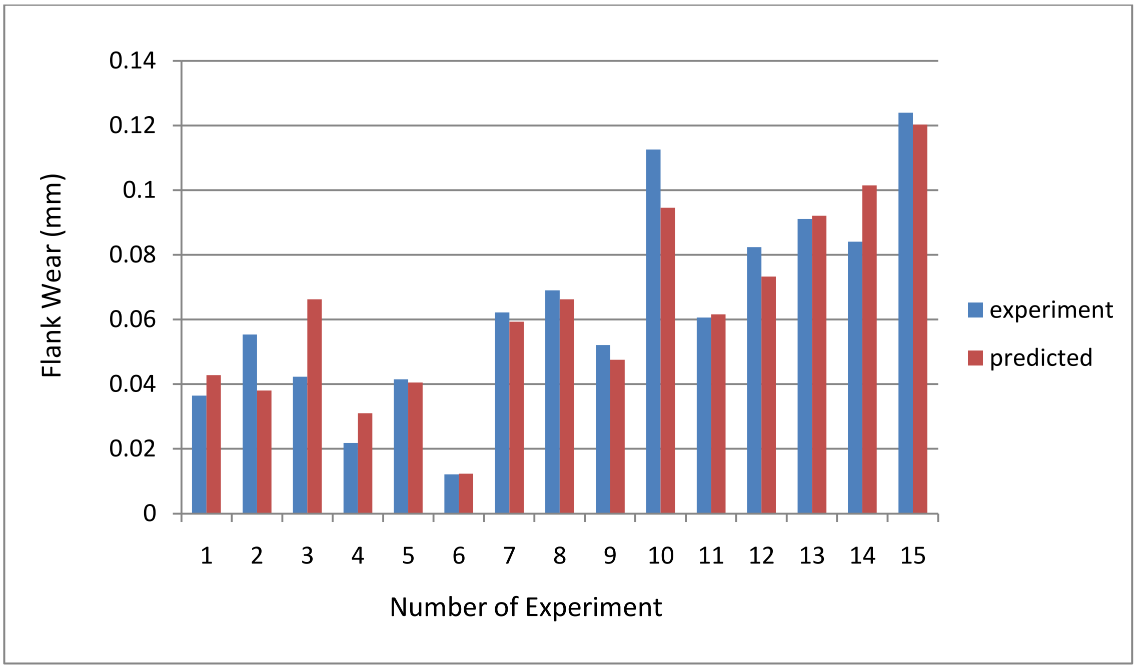


Figure 4.7(c): Tool life values obtained by experimentation and the values predicted

Fig. 4.7 (c) shows the flank wear values obtained by experimentation and the values predicted by the first order model. It is clear that the predicted values are very close to the experimental readings.

4.6 PROGRESS OF TOOL WEAR

The progress of tool wear is showed in Figure 4.8 for different cutting speed and Figure 4.9 for different of depth of cut.

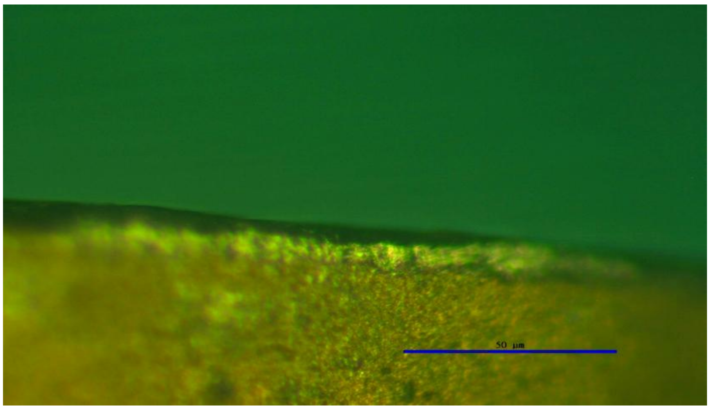
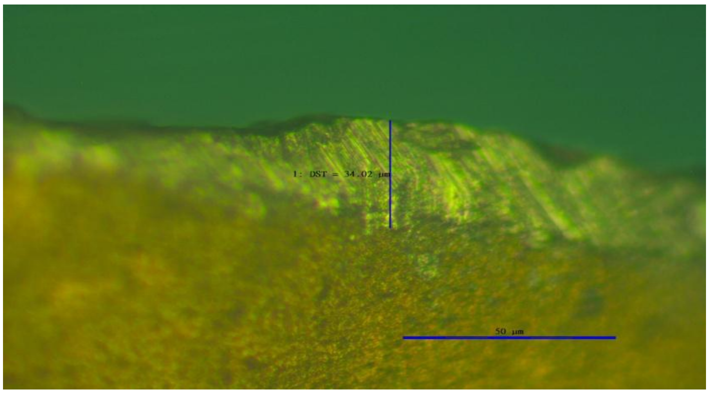
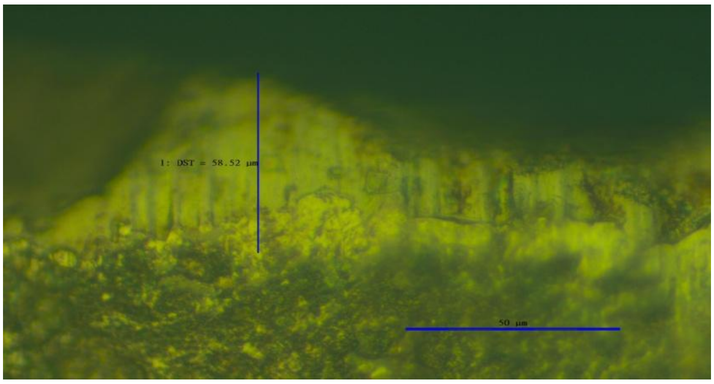
Effect of Cutting Speed	Flank Wear Progress
At 400 mm cutting length, (Vc= 180m/min) (f=0.15 mm/rev)(depth of cut 1.5)	
At 400 mm cutting length (Vc= 140m/min)(f=0.15mm/rev)(depth of cut 1.5)	
At 400 mm cutting length (Vc=100m/min)(f=0.15mm/rev)(depth of cut 1.5)	

Figure 4.8(a): Progress of tool wear due to cutting speed

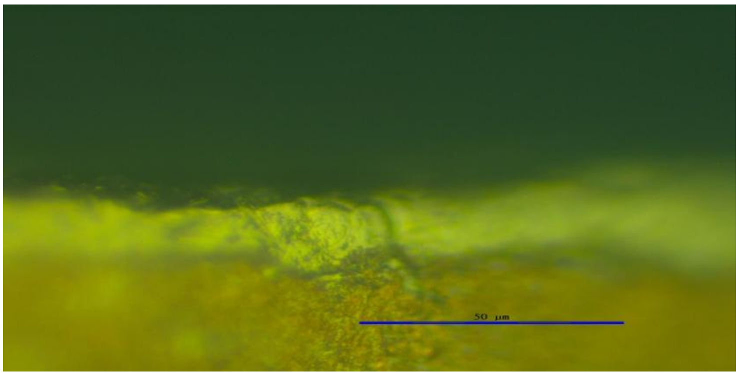
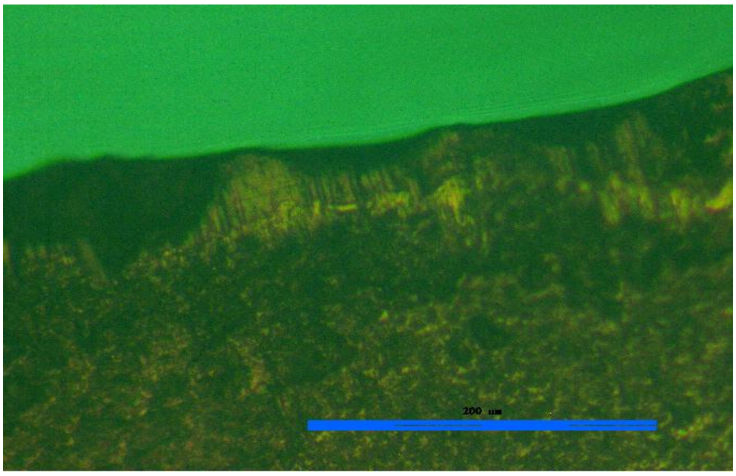
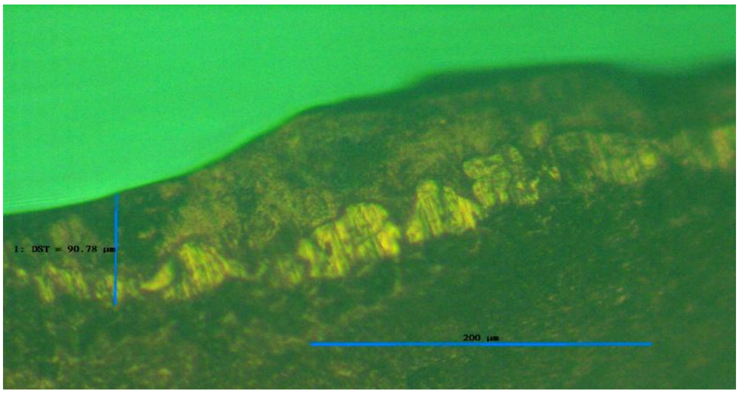
Effect of Depth of cut	Flank Wear Progress
At depth of cut=2, (Vc= 140 m/min)(f=0.15mm/rev)	
At depth of cut=1.5, (Vc= 140m/min)(f=0.15mm/rev)	
At depth of cut=1, (Vc= 140 m/min)(f=0.15mm/rev)	

Figure 4.8(b): Progress of tool wear due to depth of cut

In this experiment, the result obtained may not be accurate like what should be obtained in the literature studies. One of the reasons the result is not accurate is due to the microscope Image Analyzer that used for measure the tool wear progress. The microscope gives low and blurs vision that is hard to detect the wear of the insert. Wear occurred of the insert also are very small due to the workpiece and cutting tool that been used for the experiment. This will cause the result to be not accurate.

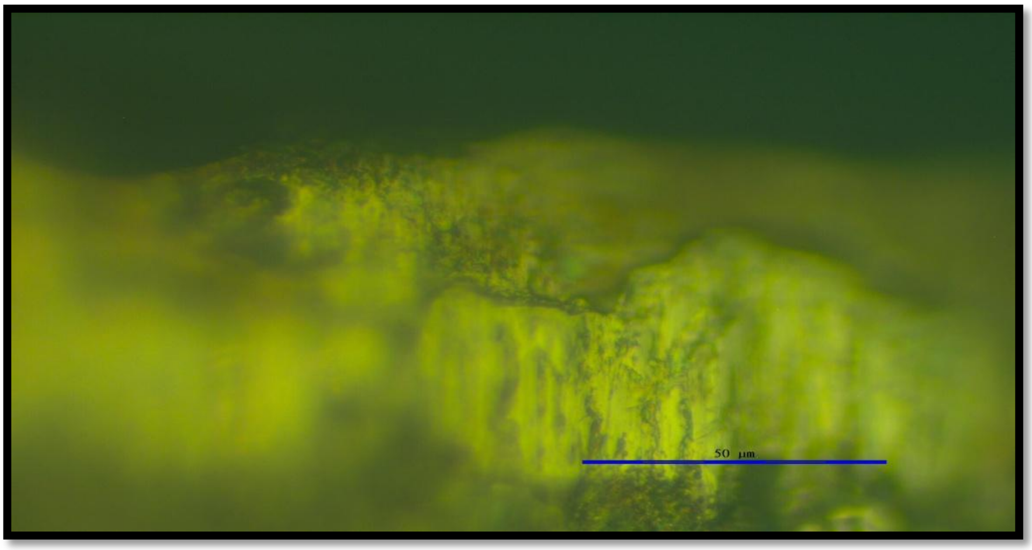


Figure 4.9: Poor image vision produce from the microscope

Furthermore, the other reason that the result obtain may not be accurate is because in this experiment, the inserts is changed when the wear on the inserts reaches its limit. But the analysis of this experiment is considering only one insert is used for the whole experiment. So this may affect the results obtained.

The human factor and reliability of the machine also contribute to the errors of the results obtained. This is because the machine may not be setup and align properly before the experiment is started and when changing the inserts, the inserts may not be positioned in the proper place that may cause the tool to used extra force to cut the workpiece, causing the heat generated and the temperature of the tool increase, and accelerates the tool wear.

4.7 SUMMARY

From the analysis and experiment that had been done, it is found that the feedrate, cutting speed, axial depth played a major role in determining the tool life. On the other hand, the tool life increases with a reduction in cutting speed and feedrate. The effect of axial depth of cut on tool life is not so significant. The speed effect is dominant followed by the feed and the axial depth of cut. Tool wear curves were plotted and the result shows that when the increase of the cutting tool feed and depth of cut, which in reduces of propagation of flank wear.

For end-milling of aluminium alloy 6061, the optimum condition that is required to maximize the coated carbide tool life are as follow: cutting speed of 18 m/s, federate of 0.2 mm/rev, axial depth of 1.5 mm.

CHAPTER 5

CONCLUSION

5.1 CONCLUSION

The study on tool wear of coated carbide inserts in machining of aluminium alloy 6061 is investigated by performing the CNC milling process with three different independent variables, which are cutting speed, axial depth of cut and feed rate. It is found that cutting speed has the most influence on flank wear compared to depth of cut and feed rate. Wear progress of the cutting tool agreeable with published report in machining of aluminum with reference of analysis and traditional plots on wear progress. Tool wear curves was plotted in Excel and the result shows that when the increase of the cutting tool feed and depth of cut, which in reduces of propagation of flank wear.

5.3 RECOMMENDATION

In this project, the experiment and analysis has been done. There are some recommendations to be considered in improving the details of this project. A better precision of microscope is highly recommended to be use for tool wear analysis. To obtain a more accurate result of the analysis, the effect of changing the inserts should be included in the design of experiment in the future.

Besides that, different types of inserts should be trying out instead of using the same type of insert when performing the experiment to investigate the different characteristic of the tool when machining titanium.

NO.	ACTIVITY	WORK WEEK																			
		JANUARY				FEBRUARY				MARCH				APRIL				MAY			
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1	RESEARCH TITLES RELEASED																				
2	RESEARCH STUDY																				
3	LITERATURE REVIEW																				
4	METHODOLOGY																				
6	LEARNING SOFTWARE																				
7	FYP 1 PROPOSAL REPORT																				
8	SUBMISSION OF THE PRESENTATION APPROVAL FORM TO COORDINATOR.																				
9	PREPARATION OF SLIDE PRESENTATION																				
10	FYP 1 PRESENTATION																				

Plan

Actual

NO.	ACTIVITY	WORK WEEK																							
		JULY				AUGUST				OGOS				SEP				OCT				NOV			
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1	LEARNING CNC MACHINE																								
2	MACHINING PROCESS																								
3	ANALYZED THE DATA																								
4	DISCUSS WITH SUPERVISOR																								
5	FYP REPORT WRITING																								
6	FYP 2 PRESENTATION AND CORRECTION OF REPORT																								
7	SUBMISSION OF TECHNICAL PAPER AND LOGBOOK																								

Plan

Actual

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APPENDIX A

PROJECT GANTT CHART

OPTIMIZATION OF TOOL LIFE IN MILLING

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Thesis submitted in fulfillment of the requirements
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