Assessment of the Uncoated Carbide inserts in end milling of Titanium Alloy Ti-6AI-4V

By

Caleb Ng Zhu Sheng

16407

Dissertation submitted in partial

fulfilment of the requirements for the

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(Hons) (Mechanical

Engineering)

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Universiti Teknologi PETRONAS

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Malaysia

CERTIFICATION OF APPROVAL

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Approved by,

____

(AP Dr Turnad Lenggo Ginta)

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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Caleb Ng Zhu Sheng

ABSTRACT

This paper investigates the effect of the uncoated carbide inserts in end milling of titanium alloy Ti-6AI-4V under dry conditions. CNC Bridgeport VMC machining was employed during the experimentations. Sandvick end milling of uncoated tungsten carbide inserts were chosen as the cutting tools. The effect of cutting parameter, i.e. cutting speed, feed, and axial depth of cut on tool wear morphology, surface roughness and chip segmentations are comprehensively investigated. Scanning electron microscope is utilized for these purposes. Flank wear has been considered as the criteria for tool failure and the wear was measured using a scanning electron microscope. Primary and secondary chip serrations also appear on the chip segmentations. The surface of titanium alloy is easily damaged during machining operations due to their poor machinability. Surface roughness generally increases with the increase of feed.

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CHAPTER 1
INTRODUCTION

1.1 Background of Study

Due to the high quality to-weight proportion kept up at raised temperatures and high imperviousness to consumption, Titanium and its compounds, specifically Ti6Al4V, are utilized generally as a part of aeronautic trade. Different standard instrument materials, for example, High Speed Steel (HSS) and tungsten carbide (WC) have been utilized as a bit of the end preparing strategy since Ti6Al4V was created. In any case, short instrument life is a champion amongst the most fundamental issues connected with the issue of updating machinability of Ti6Al4V. Ti6Al4V has high mechanical yield quality, break vitality and concoction liking. Fantastic, low thickness and extraordinary utilization resistance make Titanium combination Ti6Al4V an unmistakable material in avionics, biomechanical, marine and mixture business wanders. It additionally has to a great degree low warm conductivity which adds to the sensational shortening of hardware life in some rapid machining forms. The execution of a cutting contraption is usually contemplated in term of its life. By and large, flank wear is considered, since it generally affects the quality of the cutting wedge. Instrument wear examination is a standout amongst the most essential angles connected with growing new apparatuses for the metalworking.

Poor surface quality when in doubt happens as intended because of by convincing tool wear and constantly after cataclysmic mechanical get together frustration. Specific instrument wear structures will acknowledge grouped surface quality. In term of end planning Ti6Al4V process, the standard instrument wear plots show up as chipping, made edge, built response and material dispersing. The examination of surface quality resultant from unmistakable machining conditions considers upgrading the machining outlines. Vibration and erratic jabber continually causes appalling surface quality. To some degree, the adiabatic shearing repeat which is generally called serration repeat demonstrates the strength of the brief cutting force.

The examination of chip morphology will give key data which is key for perception the system of end handling Ti6Al4V with uncoated WC-Co implants.

1.2 Problem Statement

Recent have been separate by basic achievements in the change of cutting gadgets and machining shapes. operation with uncoated WC-Co cutting instrument implant displays a fair particular response for machining hard to-cut materials. Titanium blends have been utilized all around as a part of the flying, biomedical and automobile industry by excellence of their high particular quality, break resistance and favored resistance over crumbling. On the other hand, titanium composites are hard to machine because of their high temperature quality, low modulus of flexibility, low warm conductivity and high compound reactivity. While machining titanium mixes with routine instruments, the gadget wear rate propels rapidly.

This paper plans to give a diagram of the examination of hardware life, surface complete and chip morphology. The current overall metal cutting environment has accentuation on high productivity and cost diminishments beginning from cutting instruments. These necessities lead to the quick development and utilization of cutting devices using super hard materials. As the name derives, these materials have a noteworthy purpose of enthusiasm for hardness over routine mechanical assembly materials, which from the end customer point of view, translates into extended productivity (higher cutting speeds, longer instrument life, and so forth.). WC-Co implant associated as a cutting gadget is a late change and appraisal of money related execution of this cutting device insert in end-preparing of a-difficult to-cut material, for instance, Ti-6Al-4V titanium amalgam. Of course, cost economy depends essentially on the right choice of cutting conditions particularly in the setting of cutting parameters.

1.3 Objectives

The research overall objectives are to study the machining of Ti6Al4V using uncoated WC-Co inserts. And the research objectives are stated below.

Tool wear examination of uncoated WC-Co has been done by various masters for the machining of different materials. Instrument life models were seen in perspective of this 3 parts: cutting pace, urgent significance of cut and support. A steady adiabatic shearing rehash shows an overall stable machining methodology. Then again, as a consequence of the high warm conductivity of uncoated WC-Co material, the chip morphology is relied on to be not precisely the same as the strategy utilizing distinctive contraption materials. The surface quality coming to fruition in view of end handling Ti6Al4V with different instrument materials has not been penniless around any pro with thought about the effect of machining parameters. In addition, the endeavor is used to consider the way of Ti6Al4V finished surface and chip morphology. The examination of completed surface will be performed with the intensifying instrument and chip morphology will be researched in context of the SEM isolating photographs of utilized contraptions.

In summary, this exploration concentrates on the device life of uncoated WC-Co, chip morphology and the surface harshness of Ti6Al4V with the use of uncoated WC-Co end processing instruments. With the extended use of Titanium compound in flight, restorative and auto business wanders, there is a pressing necessity for new cutting instruments to improve gainfulness.

1.4 Scope of Study

This paper addresses the machining of Titanium Ti-AI-4V using uncoated WC-Co introduces. The techniques entwine an adequate relationship between the device life and the cutting parameters, cutting rate, Depth of cut, surface unpleasantness, et cetera. The level of study spotlights on device wear examination, the pivotal of surface seriousness study, examination of chip morphology and the yield known as reactions (device life, surface repulsiveness, cutting force of a machining process).

CHAPTER 2
LITERATURE REVIEW

2.1 Overview

An end processing is a kind of preparing cutter; it is utilized as a bit of the mechanical taking care of uses. It is perceived from the exhausting instrument in its application, geometry, and gathering. End processing are used as a piece of preparing applications, for instance, profile handling, tracer handling, face handling, and jumping. Ordinary face industrial facilities are consistently overpowering and can be unbalanced while using a greater measurement (more than 100mm) when handling certain materials for occurrence, aluminum thusly particularly masterminded face plants can be sourced that are conveyed using other base material to address this issues.

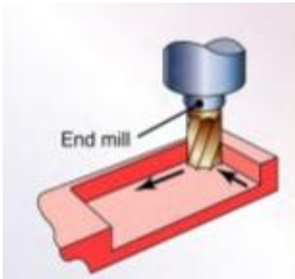


Figure 1 End milling of titanium

The extent of this writing survey concentrates on the prompt cutting power investigation of machining Ti6Al4V with end processing procedures and uncoated WC-Co after use in machining Ti6Al4V.

It focuses on the distributed writing concerning parts of hardware execution including examination of the device wear system investigation instrument wear life. Investigations of surface quality and chip morphology are another essential territory significant to this theory work so these are likewise being looked into in the take after segments.

2.2 Machining of Ti6Al4V

The high quality to-weight proportion and its amazing disintegration resistance make Titanium composite Ti6Al4V a pervasive material for use in the flying, biomedical, marine and substance business ventures. In any case, in light of its low warm conductivity, Ti6Al4V is difficult to machine. For whatever length of time that decades, various gadget materials have been striven for machining this kind of composites. With the advancement of different new cutting contraption materials, impelled instrument materials, for instance, uncoated carbide implants and polycrystalline valuable stone (PCD) have been created. These mechanical gatherings have the colossal potential for use in brisk get ready. These mechanical gathering materials join High Speed Steel (HSS), standard instrument steel, tungsten carbide (WC), (Polycrystalline Cubic Boron Nitride) PCBN, (Polycrystalline Diamond) PCD, TiAlN, and so on. The numerical articulation for figuring the cutting pace is imparted underneath:

Formulas

METRIC SIZES		
Surface Meters per Minute	=	RPM x .00314 × Tool Diameter
RPM	=	$\frac{\text{Surface Meters per Minute x 318.057}}{\text{Tool Diameter}}$
Feedrate (mm/min.)	=	RPM × CLPT Factor × Tool Diameter × Number of Flutes
Chip Load per Tooth (CLPT)	=	CLPT Factor × Tool Diameter
cm^3/mm	=	$\frac{\text{Width (mm) Depth (mm) Feedrate (mm/min)}}{1000}$
Horsepower	=	1.341 × kW
kW	=	.7457 × Horsepower

Figure 2: Formula sheet

The scopes of cutting pace, stimulate, winding cutting essentialness and focus point cutting hugeness was 50 m/min - 110 m/min, 0.08 mm/tooth - 0.14 mm/tooth, 4 mm - 6 mm, 1-3mm, solely. The surface unpleasantness was inspected. In any case, some examination works have in like way reported awful mechanical gathering execution in the machining Ti6Al4V. Tungsten Carbide and Cubic Boron Nitride (CBN) gadgets have been utilized as a bit of planning Titanium mixes with sensible results at low cutting pace of under 90 m/min. Regardless, when they are related at high cutting rate (more noteworthy than 100 m/min), the contraption life winds up being unacceptably short.

Surface roughness desire model similarly as cutting speed, manage rate and significance of cut using response surface technique has been by and large reported in composing [1,2]. It was found that cutting speed and bolster rate are the basic machining parameters influencing surface unpleasantness, while the impact of criticalness of slice is seen to be unimportant. The utilization of higher cutting pace with lower sustenance rate passes on a prevalent surface summit, for the most part in perspective of high temperature [3,4]. Azlan Mohd Zain et al.[5] inspected the impacts of winding rake edge of hardware, hardened with cutting speed and eat up upon surface ruthlessness. They reported that the cutting conditions ought to be set at most puzzling cutting rate, least empower and most fundamental stretched out rake point to perform the irrelevant surface mercilessness. While machining titanium blends harmfully an overheated white layer can be gone on which comprehends a layer being gentler or harder than the base materials Ramesh et al.[6] facilitated trials on turning of titanium blend (Grade-5) to concentrate on the impacts of cutting parameters on surface remorselessness and found that the sustenance is the most persuasive part influencing the surface unsavoriness. Jawaid et al [26] inspected the instrument wear trademark in turning titanium compound Ti-6246. It was found that inserts with fine grain size and a honed edge have a more drawn out instrument life.

2.3 Applications of uncoated WC-Co

Cemented carbide is a hard material utilized extensively as a bit of cutting mechanical congregations for machining, and in addition other propelled applications. It incorporates fine particles of carbide set up into a composite by a lock metal .The fundamental hardness and the remarkable warm conductivity make uncoated carbide inserts the most consoling device material for the machining of Titanium amalgams. A sort of carbide addition with International Standards Organizations (ISO) assignment CNGG 120408-SGF-H13A was utilized for the machining tests. The cutting apparatus utilized was a straight tungsten carbide instrument, which was an uncoated rhombic-shape, discard sort with chip breaker.[23] Numerous experts agree that the alloyed carbide gadgets are not suitable for machining titanium amalgams. The supplement comprised of 82.6 wt. % tungsten carbide, wc with 16.4 wt. % of cobalt, Co as folio. Straight tungsten carbide (WC/Co) cutting devices have demonstrated their predominance in all machining procedures of titanium compounds (Ezugwu et al. 2003). The schematic geometry of the supplement is appeared in Figure 3.

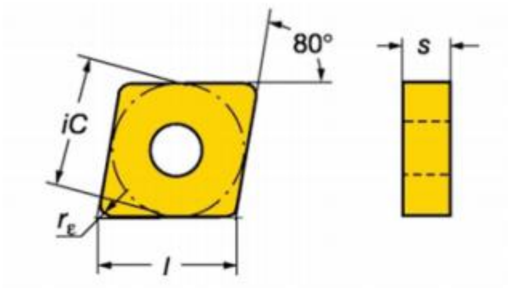


Figure 3 : Schematic geometry of the insert used in the machining

All things considered turning operations, Ginta et al created models for gadget life want in end get ready of Ti-6Al-4V utilizing uncoated carbide embeds under dry condition. They utilized negligible focal composite setup (FCD) to make the instrument life model identified with imperative cutting parameters [7]. Jawaid et al concentrated on the mechanical get together wear trademark in turning titanium compound Ti-6246.

It was found that introduces with fine grain size and a sharpened edge have a more expanded instrument life [8]. They considered flank wear up to 0.30 mm as the model for gadget dissatisfaction. Based on the examination of equipment life, surface disagreeableness, cutting forces and the wear parts, Gert et al [14] found that a decrease in nourishment and an addition in rate while using a PCD mechanical assembly conveyed better surface complete and gadget life and beat tungsten carbide instruments at various cutting paces. Che-Haron examined the gadget life and surface brutality in turning Ti-compound (Ti-6Al-2Sn-4Zr-6Mo) by utilizing two sorts of uncoated solidified carbide instruments under dry cutting condition. In his examinations he utilized four unmistakable cutting paces going from 45 m/min to 100 m/min and two specific support rates of 0.35 mm/rev and 0.25 mm/rev [9]. The significance of cut was kept reliable at 2.0 mm. He found that the supplements with better grain size have a more drawn out gadget life. Choudhury and Rao displayed another framework to upgrade the utilizing in order to cut instrument life the perfect estimations of pace and energize rate all through the cutting method [10]

2.3.1 Tool wear in conventional tool materials

Ginting and Goh dissected the instrument wear component and they inspected that break and chipping hurts happen all the more by and large in uncoated devices. Instrument life scientific model for end processing as far as the cutting parameters can be communicated as:

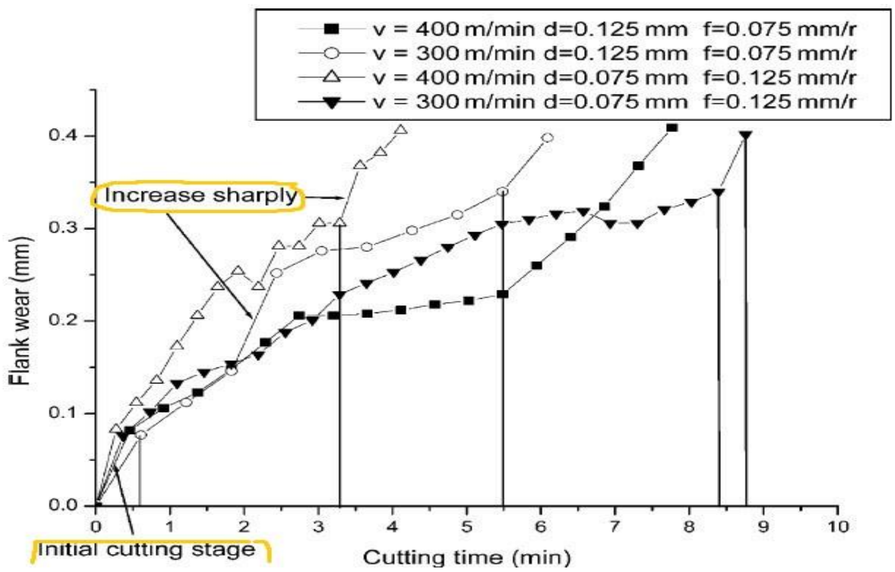
$$T = CV^{k} a^{m} f_{z}^{l}$$

Where, T is the predicted tool life (minutes), V is the cutting speed (m/min), a is the axial depth of cut (mm) and fz is the feed per tooth (mm/tooth). Below is another formula for the implementation of the cutting parameters. [40] The chip load per tooth for Titanium alloys grade 5 is 0.0048 which is highlighted with yellow below.

Titanium, Steel and High-Temp Alloys			
Titanium			
Commercially Pure	350	100	.0048
6AL-4V	230	55	.0048
6AL-6V	180	35	.004

Fig 4 . Cutting load per tooth for Titanium alloy (Grade 5)

Oosthuizen et al. [16] investigated material dissipating in fast machining of Titanium blends. Check of spread in the midst of Carbide and Titanium was found and this was seen as the real wear section. In the examination of fast get ready Ti6Al4V with Binderless Cubich Boron Nitride (BCBN) devices, Wang et al. [17] examined the contraption wear progress in various working conditions. As appeared in Figure 1.1 shows which is refered to from Wang's study, the best slicing time is near 9 minutes before the flank wear came to 0.4 mm when the cutting velocity was 300 m/min, nourishment was 0.125 mm/r and focus cutting importance was 0.075 mm.



Graph 1 - The tool wear evolution in different working conditions .

For upgrading and fortify the instrument life, standard gadget materials, for instance, for occasion, HSS and WC were in like way utilized as a part of the technique however with unmistakable cooling systems [18].

Bermingham endeavored the instrument execution of WC in cryogenic machining Ti6Al4V. As appeared by his examination, the new cryogenic cooling technique satisfactorily added to the instrument life of WC by up to 58 % when separated and that of dry machining framework. In this study, the brain boggling mechanical gathering wear systems were seen to be scrambling and handle.

There are alert tensions catching up on the instrument accomplished by blueprint of serrated teeth over the whole cutting pace range [19] and the high substance reactivity of Ti6Al4V, particularly at cutting temperatures in abundance of 500ºC, causes high dispersing wear rate. At temperatures above 500 ºC titanium has solid preference to take after, this property of titanium composites prompts seizing of chips onto the cutting device surface bringing on a made edge which accomplishes brisk instrument disappointment [20]. The blended impact of uncommon yield expand and low Young's modulus awards titanium blends just negligible plastic mutilations and enables redirections, jibber babble and work piece change far from device [21]. Every one of these variables lead to lively cratering and plastic twisting of the cutting device accomplishing device dissatisfaction which is the reason Ti6Al4V is named a hard to machine material [22]. By suitably selecting the contraption material and cutting conditions a sufficient rate of equipment wear may be refined and subsequently cutting down the total machining cost [25].

2.4 Surface quality

Surface roughness, which is estimation joined with the method for the completed surface, is a champion amongst the most fundamental parameters which can be utilized as a metric relating to the machinability of Ti6Al4V. Unmistakable working conditions may understand the developments to the surface uprightness which combines surface cold-bloodedness. For example, Cai et al. [24] showed that Minimum Quantity Lubrication accomplishes the best oil influence and the longest instrument vicinity with decreased surface brutality .in like manner, estimation of occurring surface finishing and part drives in the midst of cutting operations are key variables (Ezugwu et al. 2003).

Emmanuel investigated the surface respectability and gadget execution of uncoated carbide by applying particular cooling conditions in the turning shapes [15]. This concentrate additionally found a 5-20 % setting of the completed surface. Considering the examination of hardware life, surface pitilessness, cutting qualities and the wear parts, Gert et al. [14] found that a decrease in nourishment and an enlargement in pace while utilizing a PCD contraption improved surface repulsiveness and instrument life and beat tungsten carbide gadgets at different cutting rates. Chip morphology and division have administering impact in picking machinability and mechanical get together wear amidst the machining of titanium amalgams. At lower cutting speeds the chip is a great part of the time sporadic, while the chip persuades the chance to be serrated as the cutting velocities are augmented [11].

Again solidifying of the machined surface was found in the investigation. In spite of the fact that uncoated carbide instrument material is exceptionally responsive with titanium amalgams, the synthetic response shapes a layer of Titanium carbide which ensures the device by framing boundary to further dispersion. Past studies demonstrated that the device life of carbide diminished rapidly at higher cutting pace. [28] Venkatesh in (1980) strongly approved this result, who performed apparatus wear examinations on some cutting device materials According to Groover [36], the surface unpleasantness which identifies with the typical of the vertical deviations from apparent surface over a beyond any doubt measuring length on the surface of work piece, is all things considered used to evaluate the finished surface quality. The announcement of typical brutality can be described as Equation (2-1).

$$R_a = \int_0^{L_m} \frac{|y|}{L_m} dx$$

(2-1)

Where x is the differential length of the subjective measuring length (Lm) on workpiece surface. Furthermore, the |y| shows the outright separation from the top ostensible surface. Figure 2-1 represents the parameter x, Lm and |y| in the measuring part. Another expression of normal roughness is

$$R_a = \sum_{i=1}^{n} \frac{|y_i|}{n}$$

(2-2)

Where n is the number of measuring peak and yi is the absolute height of every

Measuring peak on finished work piece surface.

2.5 Chip morphology

The serrated chip is one of the basic warm qualities in get ready Ti6Al4V. The serration is known not the result of adiabatic shearing (ABS). By et al. [29], ABS dependably happens in the zone which encounters a high strain rate. Sima and Ozel found that the ABS social occasions could be watched unmistakably when the cutting pace was higher than 60 m/min with the food above 0.05 mm/rev [30]. Precisely when these machining parameters were enough broad to accomplish clear chip serration, the chip serration rehash was delicate to the machining parameters, geometrical impact, the warm properties of the cutting contraption and of the work piece and the cooling suitability. At lower cutting speeds the chip is as often as possible convulsive, while the chip gets the opportunity to be serrated as the cutting rates are extended [27]. The examinations of division repeat, its effect on prattle advancement and the effect of work piece preheating on chip division and babble were contemplated by Amin and Talantov [26].

Activities to depict the chip morphology in cutting titanium and its blends retreat to the work performed by Cook in 1953 [12]. He assessed the chip morphology of titanium at specific cutting rates and proposed a thermodynamic hypothesis for chip change. Nakayama et al. [35] and Shaw and Vyas [36] proposed the sporadic breakdown strategy hypothesis in machining hard steel. Komanduri et al. [37] concentrated on the chip course of action strategy amidst the cutting of Ti–6Al–4V and proposed the without a doubt appreciated calamitous shear chip' theory. Other early examinations concerning chip division in the cutting of titanium composites were performed by Lee [38] and Gente and Hoffmeis.

During the time spent machining Ti6Al4V, Gert et al. [13] said that at high cutting speeds the properties of titanium alloys Ti6Al4V causes complex wear components on the cutting device as a result of the titanium combination's low warm conductivity of 7W/mK which is 86% lower than that of AISI 1045 steel. The warmth impacted zone in titanium machining is minimal because of its superb keeping up property at lifted temperatures moreover its ability to casing kept shear bunches in the midst of the machining strategy. It shapes short chip-device contact length of around 33% of the contact length for steel [31].The serration recurrence of the chips is one of the essential qualities for restricted shearing impact. This parameter ordinarily demonstrates the shearing velocity and neighborhood geometry of shearing groups. As indicated by the investigation led by Molinari et al. [32], the chip serration recurrence was relative to the cutting velocity. Miguélez considered the chip serration by utilizing FEM models [33]. Their outcomes demonstrate that the geometrical parameters and grinding are critical to the chip morphology. Besides, Baker has additionally found that a lower warm conductivity could bring about a higher serration recurrence [34]. The cutting pace reflects the rate of distorting and shearing. According to Wang's examination, the shearing strain rate in the chip thickness heading within the shear band can be conveyed as Equation (2-3)

$$\dot{\gamma} = \frac{v(H-h_1)\sin\gamma_0}{\delta H\cos(\phi-\gamma_0)} \quad (2\text{-}3)$$

Where v, H, h1, φ, δ, γ0are cutting speed, maximum thickness of saw tooth chip, chip thickness at local shear deformation, shearing angle, saw tooth chip shear band width and rake angle, respectively.

CHAPTER 3
METHODOLOGY

3.1 Project Framework

This chapter explains how the project is conducted to attain the goal of the project. The division of work throughout the FYP 1 and 2 semesters is depicted in the Key Milestone and the Gantt chart.

End milling tests were driven on a CNC preparing machine (Bridgeport VMC 2216) with full soaking cutting under dry condition. Titanium combinations Ti-6AI-4V bar was used as the work-piece. Machining was performed with an 80 mm separation crosswise over end-processing plant gadget holder fitted with one supplement. Uncoated carbide supplements were used as a part of the tests. The trials were continue running under dry conditions and each test was started with another front line. The addition is set at the optical magnifying instrument to distinguish the microstructure before processing. Contingent on the cutting conditions and wear rate, machining was stopped at various break of cutting length to record the wear of the supplements. Picked diverse cutting conditions for the experimentation were determined.

After each test the mechanical assembly wear and surface finish was measured under an amplifying instrument to analyze the gadget wear. Scanning electron amplifying lens (SEM) or optical magnifying lens was utilized to scrutinize the gadget device life, wear morphology and chip divisions. Flank wear has been considered as the criteria for apparatus disappointment and the wear was measured under an optical magnifying lens. Further testing was halted and an addition rejected when a normal flank wear of the WC-Co more noteworthy than 0.30 mm was recorded. The reason is on the grounds that the suitable wear for end processing in High-speed steel apparatuses is 0.3mm.

3.2 Tools

With the end goal of this experiment, a few instruments are used to perform the assignments in like manner.

Figure 6 Scanning electron microscope

Scanning electron microscope (SEM)

A type of electron amplifying lens (SEM) is a sort of electron filtering so as to amplify instrument that conveys pictures it with a connected with light emanation and is used to explore the device wear morphology and chip divisions.. The electron bar is all things considered inspected in a raster clear illustration, and the bar's position is joined with the recognized sign to convey a photo. Illustrations can be found in high vacuum, in low vacuum, and in wet condition.

Figure 7 Uncoated carbide insert

Uncoated carbide inserts

It is utilized as a cutting apparatuses for this task, supplanting Carbide cutting devices in numerous non-ferrous machining applications.

Figure 8 Optical Microscope

Optical Microscope

The capacity to make an amplified photo of an illustration includes three crucial components of "procuring an unmistakable, sharp picture", "changing an intensification", and "bringing into center hobby". An optical system for executing these limits is implied as a recognition optical structure.

Figure 9 CNC Milling machine

Bridgeport VMC 2216

End milling machining of titanium alloy (grade 5) were conducted on this machine with full immersion cutting under dry condition.

Figure 10 Surface Roughness Machine

Mitutoyo CNC Surface Roughness Measurement Surftest

The machine is utilized to gauge the normal surface unpleasantness of the titanium square.

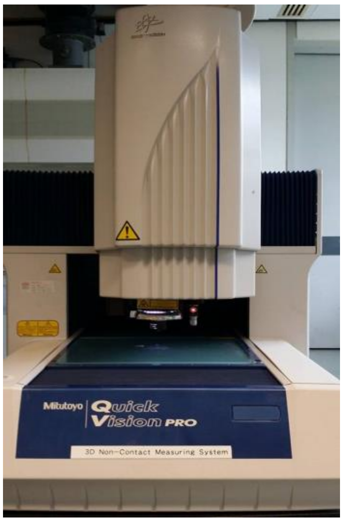


Figure 11 3D Non- Contact Measuring Machine

Mitutoyo Quick Vision Elf Pro

This machine is used for measurement of the tool wear of the uncoated carbide inserts with a specific laser and 3D work piece measurement.

Table 1 Cutting parameter

Test	Spindle Speed SS (RPM)	Feed fz (mm/min)	Depth of cut a (mm)	Speed S (m/min)
1	637	122.30	0.2	40
2	1273	244.41	0.2	80
3	1910	366.72	0.2	120
4	2546	488.83	0.2	160
5	2865	550.08	0.2	180
6	3183	611.36	0.2	200
7	3501	672.19	0.2	220
8	3820	733.44	0.2	240
9	4138	794.50	0.2	260

3.3 Gantt Chart and Key Milestone

Flowchart

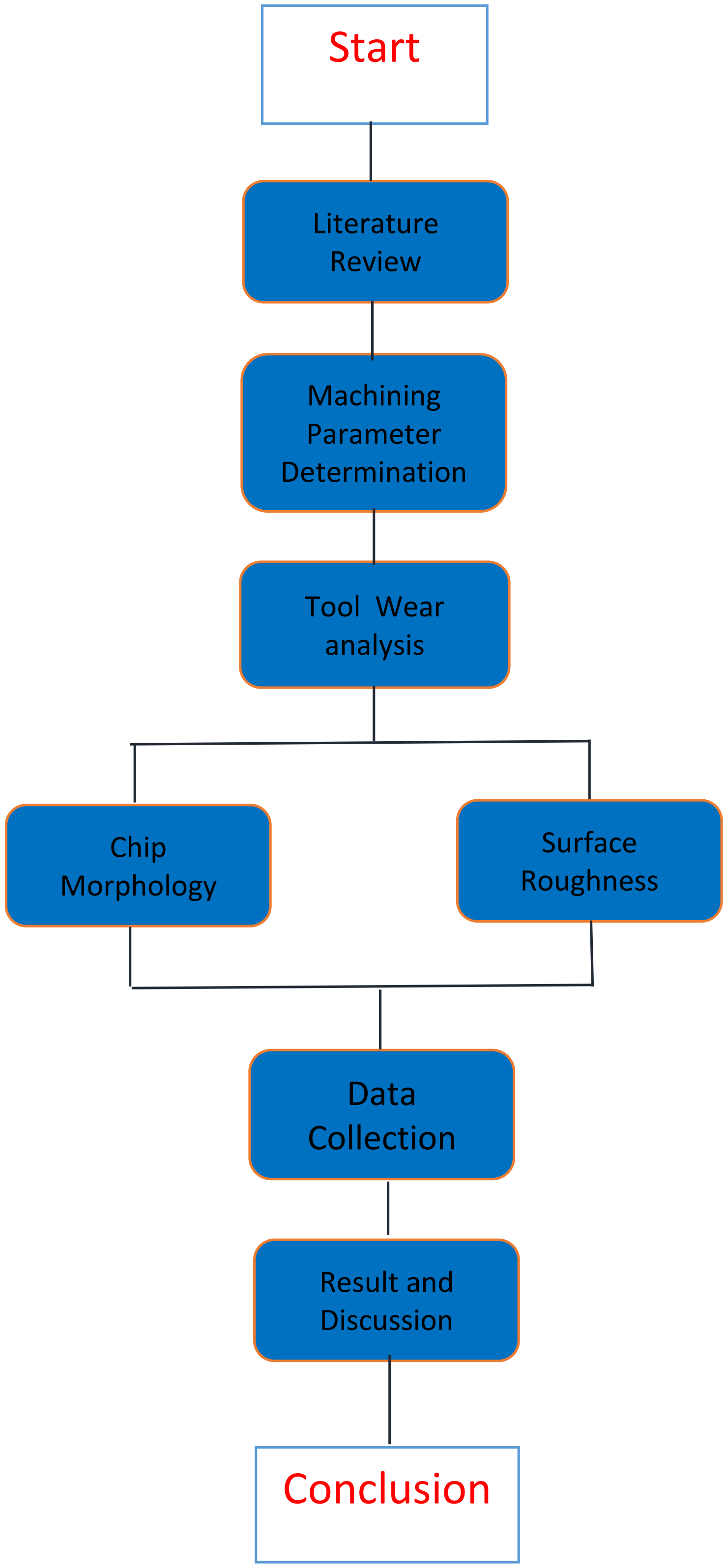


Figure 5 Methodology Framework

FYP 1

NO	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Determination of Project subject														
2	Literature Review														
3	Determining Cutting Parameter														
4	Discussion with Lab Technicians														
5	Submission of external Proposal														
6	Proposal Defence														
7	Preliminary Experiment														
8	Train to use CNC machine														
9	Submission of Interim Report														

	FYP 2														
NO	**Detail/ Week**	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Conduct Experiment for Tool wear														
2	Conduct Experiment for Surface Roughness														
3	Conduct Experiment for Chip Morphology														
4	Analysis of Results and prepare technical report														
5	Progress Report														
6	Conclusion and Recommendation														
7	Pre-SEDEX														
8	Final report Submission														
9	Technical Report														
10	Dissertation														
11	Viva														

CHAPTER 4 RESULTS AND DISCUSSION

4.1 Tool life and failures

4.1.1 Tool life and wear study

This area concentrates on the instrument wear of uncoated carbide inserts in end treatment of Ti6Al4V. It joins three perspectives: the begin of breaking, instrument life examination and fractograph examination. As showed up by the examination of SEM photos, the chipping and delamination were seen to be the premier wear outlines. Contraption life portrays the relentless disappointment of cutting gadgets in context of ordinary operation. It is a term once in a while associated with tipped instruments, depleting contraption, or bores that are used with machine gadgets.

Sorts of wear include:

i. Flank wear in which the bit of the instrument in contact with the completed part disengages. Can be outlined utilizing the Tool Life Expectancy relationship.

ii. Crater wear in which contact with chips separate the rake face. This is to some degree common for mechanical social affair wear, and does less break down the utilization of an instrument until it convinces the opportunity to be dead sufficiently honest to goodness to comprehend a bleeding edge dissatisfaction.

iii. Build-up edges in which material being machined makes on the cutting edge. A few materials (astoundingly aluminum and copper) tend to strengthen themselves to the front line of a contraption. It happens most a huge part of the time on gentler metals, with a lower liquefying point.

iv. Edge wear, in drills, proposes wear to the external edge of a penetrating device around the cutting face brought on by over the top cutting rate

Tool life examination, is the most fundamental plots for choice and utilization of new contraption material. To comprehend the contraption wear characteristics is fundamental for the sensible applications. The calamitous contraption wear can understand restricted nature of surface completion. By 8688 - 1 and ISO 8688 - 2 [104], particularly, instrument life testing in face taking care of and end setting up, the sorts of gear wear include: Flank wear (VB), Face wear (KT), Chipping (CH), Cracks (CR), Flaking (FL), Plastic Deformation (PD) and Catastrophic Failure (CF).

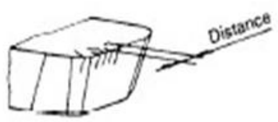
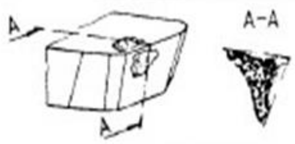
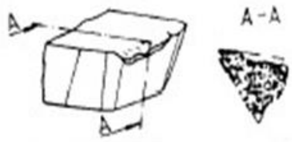
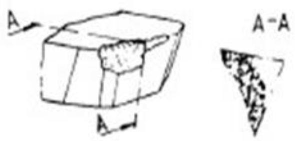
Code	Description of tool deterioration		
Basic form / Distribution / Subdivision	Tool deterioration phenomena	Criteria, mm (S / N / L)	Illustration
CR 1 2 3	Cracks Cracks perpendicular to the edge Cracks parallel to the edge Irregular direction	The number of the largest cracks and the mean distance between them shall be recorded	
FL	Flaking	Could be used as criteria in exceptional cases	
PD	Plastic deformation		
CF	Catastrophic failure		

Table 2 The criterion of tool wear

Tool life criteria can be characterized as foreordained numerical estimation of a device weakening which can be measured:

• Actual cutting time to failure

• Cutting velocity of a given time

• Length of work machine

4.1.2 Analysis of Tool life

The tool life has been surveyed, the execution of uncoated additions machining tests are done utilizing end processing process. The cutting parameters are recorded. It has been viewed as this surface harshness worth is worthy by the commercial ventures for completing cut. In the wake of getting the instrument life for differing cutting speeds, the qualities are plotted on the chart for the uncoated carbide embeds. The diagrams have been appeared in Figure 12. It has been watched that the bend is verging on direct which show that as the cutting pace expands, the device life diminishes quickly.

Amid the tests, uncoated carbide embeds with slicing speeds changing from 40 to 260 m/min are utilized under dry machining condition. The separation of the investigation for the cutting is altered at 18cm. To comprehend the device wear, the checking electron minuscule pictures have been uncovered that at lower cutting rates, at first hole wear has been seen on the device tip and in the wake of machining a specific timeframe the flank wear has been taken note. Once in a while chipping has been seen subsequent to machining longer period at lower cutting speeds however it is exceptionally normal at higher cutting paces. At the point when the device tip is totally worn up the surface begins to fall apart quickly. Affidavit of guardian material on device tip and the developed edge have been seen also. The wear on the significant flank is normally as flank wear.

Flank wear instead of hole wear which is recognizable in the machining of bendable materials, flank wear can be accessible under each and every cutting condition. It insinuates the wearing of the flank face, starting at the forefront and intelligently made to the diving and sideways. It is on a very basic level achieved by scratched territory. On account of medium cutting rate, low nourish and pivotal profundity of cut, scraped area/whittling down wear is apparently happened near the rake face. It was because of the way that steady loss, chipping, and plastic twisting are the significant reasons for wear when machining of air motor composites with uncoated carbide apparatuses at lower rate condition. At low nourish, the burdens demonstration near the front line and prompt its escalated plastic deformation.

As the cutting parameters are increased, non-uniform wear are prevalent from nose to flank zone. At high cutting speed and low support, a mix of spread, wearing out and plastic contorting was accessible as showed up in Fig 13, Fig 14 and Fig 15. This is related to the effects of high cutting speed in growing temperature in the midst of cutting. In irregular cutting like end preparing, a cyclic warm push is fundamentally unmistakable, which makes exhaustion soften and up the long run starts the wearing. At higher cutting speed and empower, wear essentially involves non-uniform wear in light of plastic deformation at the nose fragment as showed up in Fi. . Mix of high cutting speed and maintain impressively grow the uneasiness near the nose and flank zone, delivers high temperature and backings high wear rate.

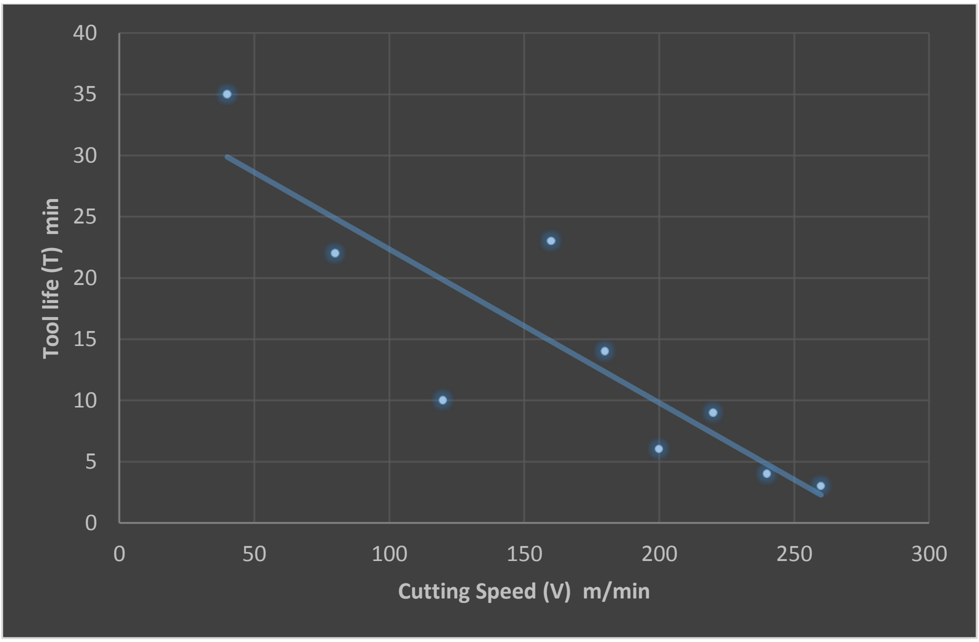


Fig. 12 Tool life curve for uncoated carbide inserts

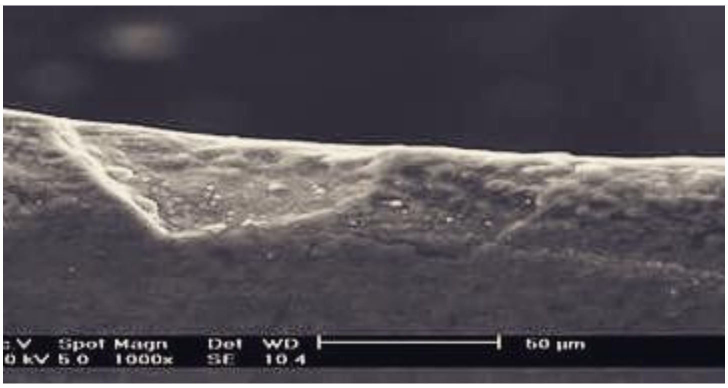


Figure 13 SEM views of Abration/BUE (V = 80 m/min, feed =

244.42mm/min)

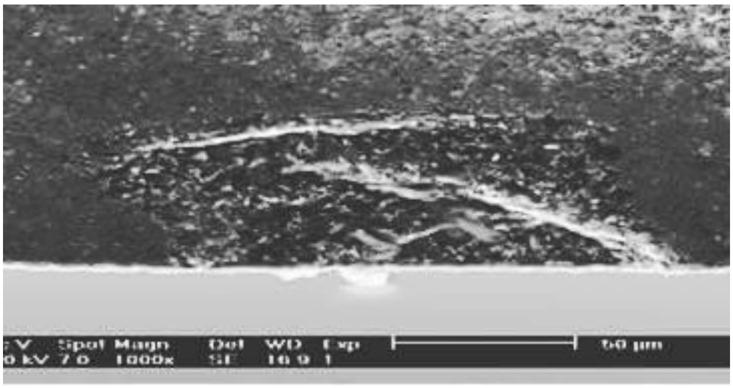


Figure 14 SEM views of Plastic Deformation (V = 200 m/min, feed = 611.4mm/min)

Figure 15 SEM views of Diffusion (V = 160 m/min, feed = 488.83mm/min)

It is associated in like manner to the way that machining at higher pace conditions tend to make higher temperature close to the nose achieving over the top uneasiness at the instrument nose making plastic bending and coming about device disillusionment. Moreover, the rake and flank wear were unmistakably come to fruition in light of deterioration spread and whittling down while machining titanium amalgams. Crumbling scattering wear won on the rake face where unfaltering misfortune was the engaged wear part. Due to the high invention reactivity of this amalgam, it has penchant to weld to the cutting gadget in the midst of machining which prompts chipping and inconvenient gadget frustration. The region of created edge (BUE) is seen in the midst of cutting as showed up in Fig 13. It is related to the high temperature delivered in the midst of cutting which prompts a development in substance reactivity between chips or materials and cutting mechanical assemblies, and in this way prompts the game plan of BUE.

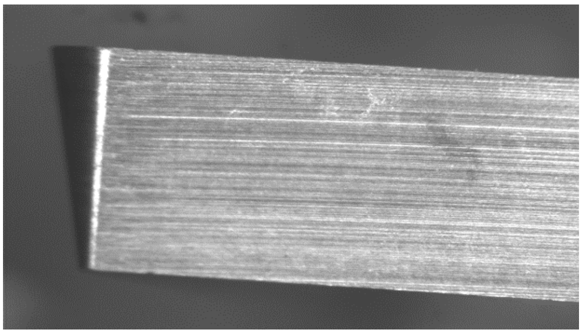


Figure 16 SEM views of the WC–Co inserts before machining experiments.

SEM perspectives of the supplements are appeared in Figs.17 after the machining tests for WC–Co. Considering the Fig 17, it can be watched that there is least clearing of metal at 40m/min. In any case, it can be perceived from Fig.17 that wear is all the more even and obvious at 80 m/min other than uniform however more kept up at 120 m/min, acknowledged generally by dispersing. Flanking can be seen at Fig 17 when the rate is at 200 m/min. As to last two cutting paces wear is fundamentally shocking in nature and the instrument of wear transmit an impression of being a mix of diffusing and shallow plastic misshaping bringing on harm of the whole working bit of the gadget. It can be closed from the above examination that, the crucial wear systems in charge of the disappointment of the mechanical gathering as a result of WC–Co expansions are spread and shallow plastic mutilation. Typical flank wear (VB) versus cutting speed charts for the supplement are showed up in Graph 2. It can be seen from the diagram that by virtue of carbide increases instrument wear progresses at the cutting pace of 120 m/min up to 10min of machining and 6 min for the cutting pace of 200m/min, while wear proceeds exponentially in substitute rates, with short gadget life especially at the last two rates. In perspective of the table underneath, the increments must be changed around 4 times all through the trial as the flank wear have surpassed the VB3 ≤0.3mm in light of the sensible wear land.

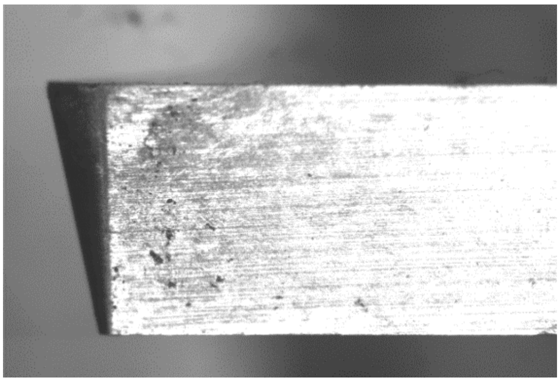
Speed S (m/min)	Flank wear (VB)	Tool life/Time (min)
40	0.115	13
80	0.223	12
120	**0.34**	10
160	0.19	9
180	0.27	8
200	**0.36**	6
220	0.29	5
240	**0.38**	4
260	**0.32**	3

Table 3 Tool life of uncoated carbide inserts after experiment

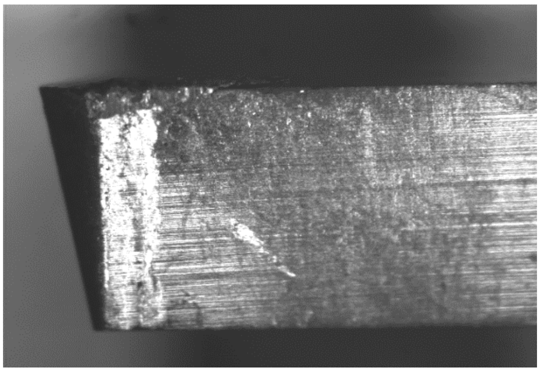
Graph 2 Flank wear vs Tool life

The best balance between cutting speed and device life is given by end processing at cutting velocities of 80–100 m/min where VB3 ≤0.3mm and apparatus life extending from 20min to 25 min. Limited flank wear (VB3) is the predominant disappointment mode for both devices because of the convergence of coupled thermos mechanical burden at the apparatus driving edge. Notwithstanding, as indicated by

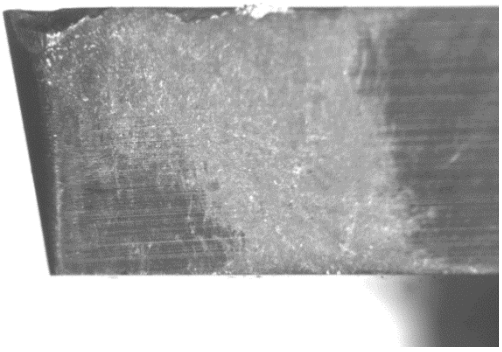
ISO 3685, the device life more than 2 min is an acknowledged worth for machining a costly material.



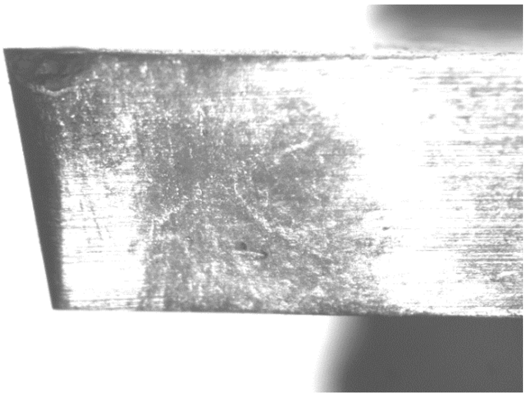
V=40 m/min, T=35 min



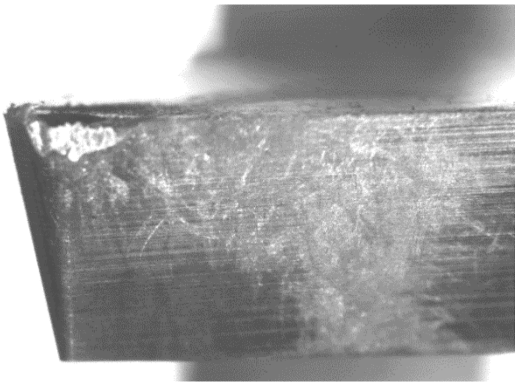
V=80 m/min, T=22 min



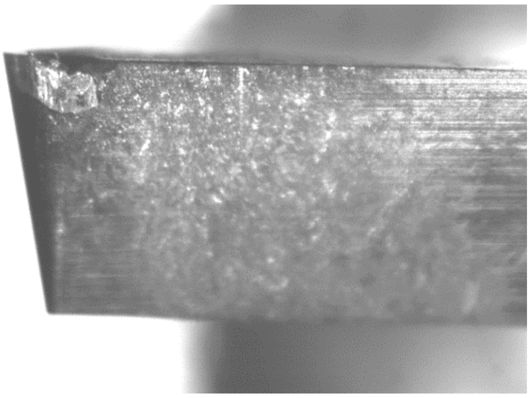
V=120m/min , T =10min



V= 200m/min, T=23min



V=240 m/min, T=9 min



V=260 m/min, T=3 min

Fig. 17 3D Non contact measuring machine views of the WC–Co inserts at the end of machining experiments.

4.2 Surface quality and chip morphology

This area produces a gander at the results of machining parameters on surface quality and reviews the chip morphology. It is comprehended that an enlargement in machining parameters, for example, cutting rate, strengthen and focus point cutting hugeness can get the mechanical gathering life or augmentation the device wear which will at long last incite low nature of surface repulsiveness. This study streamlines the inspecting to machine parameters the impact of machining parameters in transit of surface wrapping up. The new divulgences uncover that the serration rehash of the unpredictable chip has changed amidst machining philosophy. The difference in the brisk cutting power shows the shakiness of the serration rehash. Surface ruthlessness expect a vital part in picking how an ensured thing will interface with its surroundings. Shocking surfaces for the most part wear more rapidly and have higher breaking down coefficients than smooth surfaces.

All around, the geometric parts which join the instrument geometry, machining parameters and gadget method for technique can impact the surface harshness all the while. In addition, the material properties of equipment and work piece can in like manner impact the surface harshness. In the midst of the strategy, developed edge on the device nose will happen when there is generous work done on the machining of material. The development edge can hurt the finished surface. The pounding effect is also a standard perspective which impacts the surface culmination. In view of the low warm conductivity of work piece materials, the cutting warmth created in the process can't be scattered rapidly after one preparing cycle before the accompanying. Warmth conglomeration will thusly come about and the close-by cutting temperature will rise through and through. This situation may finally bring about curving of the finished work piece. The properties of equipment wear and vibration in the process are similarly the basic variables which add to a poor surface finish quality

Chip morphology examination has been performed as usual practice over numerous decades. The chip serration is known as the consequence of the adiabatic shearing impact. By and large, this impact indicates extraordinary confinement.

In numerous studies, the warmth conduction is overlooked as a result of it is moderately ease back contrasted with the quick distortion process. The qualities of adiabatic shearing impact incorporate the shearing recurrence and the geometrical limitations of adiabatic shearing groups. From the perspective purpose of material building, there are some basic elements which influence the adiabatic shearing impact.

In the processing process, it is understood that the warm properties of instruments and work piece affect the adiabatic shearing sway. The slicing speed is thought to be the significant variable in choosing the strain rate which also impacts the adiabatic shearing sway. The cutting pace reflects the pace of disfigurement and shearing.

Tensile strength (Mpa)	0.2% proof stress (Mpa)	Elongation (%)	Density (g cm^{-3})	Melting point (°C)	Measured hardness (C.I.-99%)[a] HV_{100}	Thermal conductivity at 20°C(W/mk)
900-1160	830	8	4.5	1650	Min.Z341, Max. Z363	6.6

Table 4 Mechanical properties of titanium alloys

4.2.1 Analysis of Chips Morphology

Chips were investigated under SEM to watch the general delineation of division and the commonness of chip serration. Division (typically known as saw-tooth chip) is a trademark state of the chip while machining titanium composites. This chip sort is unmistakably different to the "relentless" or 'uniform-shear' chip which is limited amidst the machining of titanium blends under customary/low speed cutting conditions. The upsides of Scanning Electron Microscopes over Transmission Electron Microscopes is that SEM produces 3D pictures while TEM just makes 2D pictures. Couple of representations of chip micrographs are showed up in Fig 18 for WC–Co presents. It can be seen from the SEM points of view of chips that there are chip serrations running over the whole width of the chips at all the examined cutting paces from 40 to 260 m/min. These teeth are termed as 'vital serrated teeth'. There show total of a couple serrated pieces at the upper – free edge (more unmistakable by brilliance of WC–Co increments). These more vital coagulated sections are termed as 'discretionary serrated teeth'. It demonstrates the cross fragment of chip morphology.

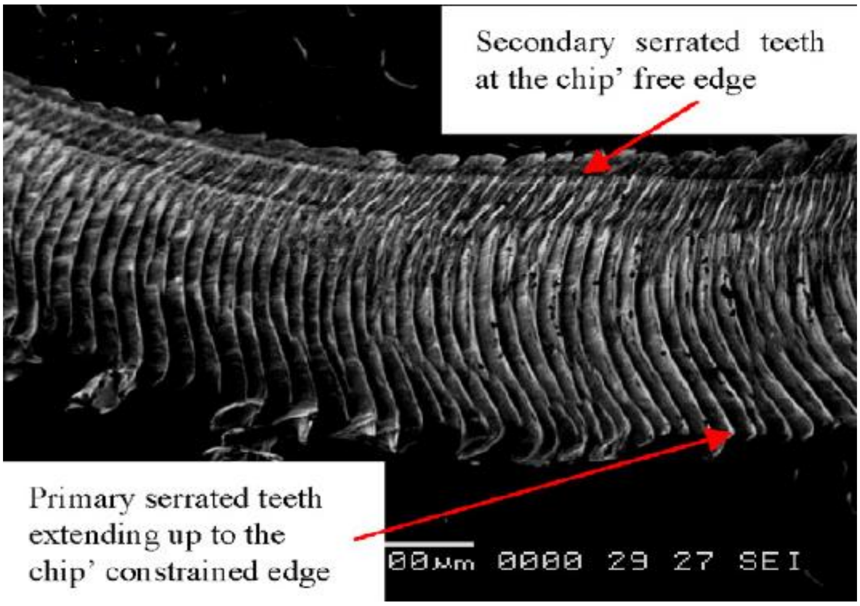


Figure 18 SEM micrographs of chip's top view for uncoated carbide inserts: (a) at 120m/min.

The chip micrographs of Titanium composites on the free surface are showed up in Fig 19,20,21,22. As can be seen from the figure, the free surface of the chip has a free and lamella structure, which is refined by the shearing framework. The free surface has two areas of different presentations, the tremendous piece bound by the side cutting edge and the corner section framed by the corner bleeding edge. The lamella structure in the essential degree is parallel to the side forefront, while the inclined lamella structure in the corner territory is generally parallel to the instrument nose edge. For the most part, all cutting parameters add to the methodology and the district of the lamella structure.

Regardless, cutting speeds and support rates are the two central technique parameters impacting the size and state of lamella structures of the free surfaces as indicated by the SEM pictures, while the combinations in perspective of the hugeness of cut are significantly more diminutive. In this manner, this study concentrates on the impacts of cutting speed and engage rate on chip morphology. Precisely when cutting speeds and bolster rates are bearably low, little yet uniform lamella structures are formed as appeared in Fig 19. The assignment of the lamella is astoundingly uniform and the common lamella thickness is sensibly unsurprising. With the augmentation in cutting speeds and bolster rates, more noteworthy lamella structures seeing width and hugeness happen as appeared in Fig 20, which displays that saw-tooth pitch and the degree of saw-tooth stature to chip thickness increment.

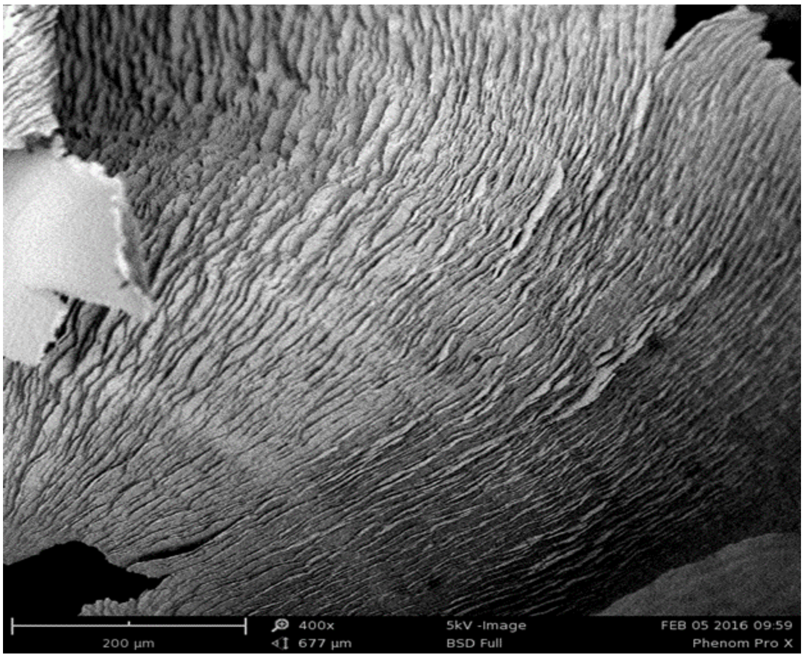


Figure 19 SEM micrographs of chip's top view for uncoated carbide inserts at 100m/min

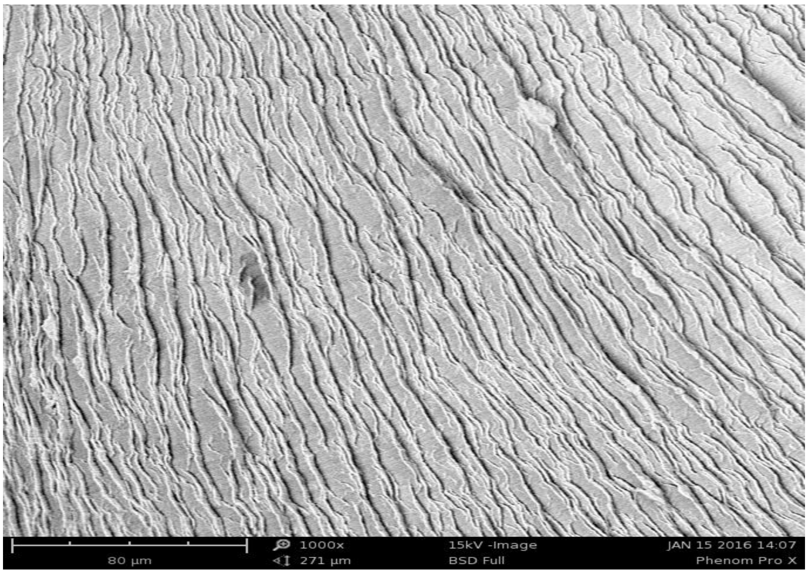


Figure 20 SEM micrographs of chip's top view for uncoated carbide inserts at 160m/min

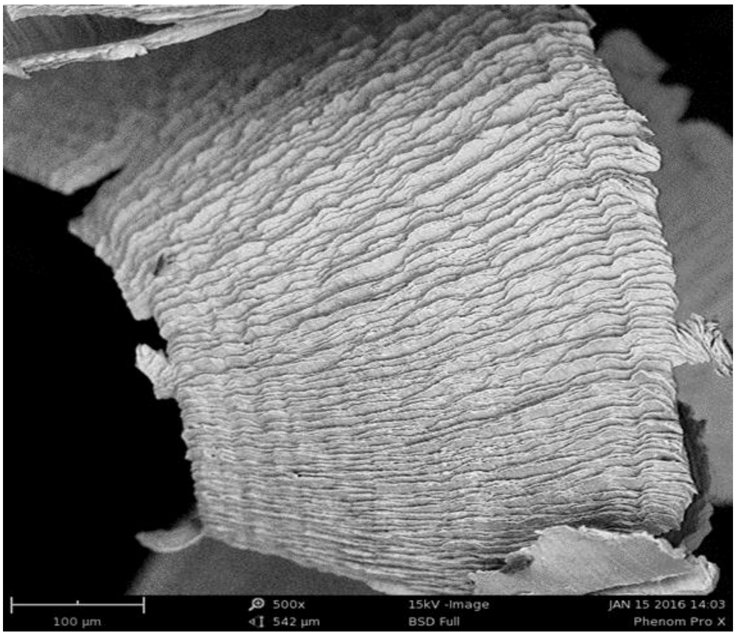


Figure 21 SEM micrographs of chip's top view for uncoated carbide inserts at 180 m/min

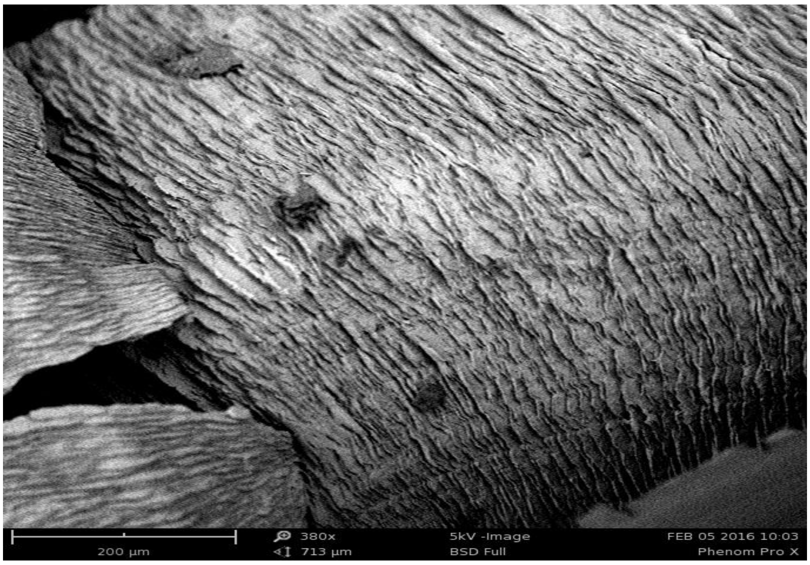
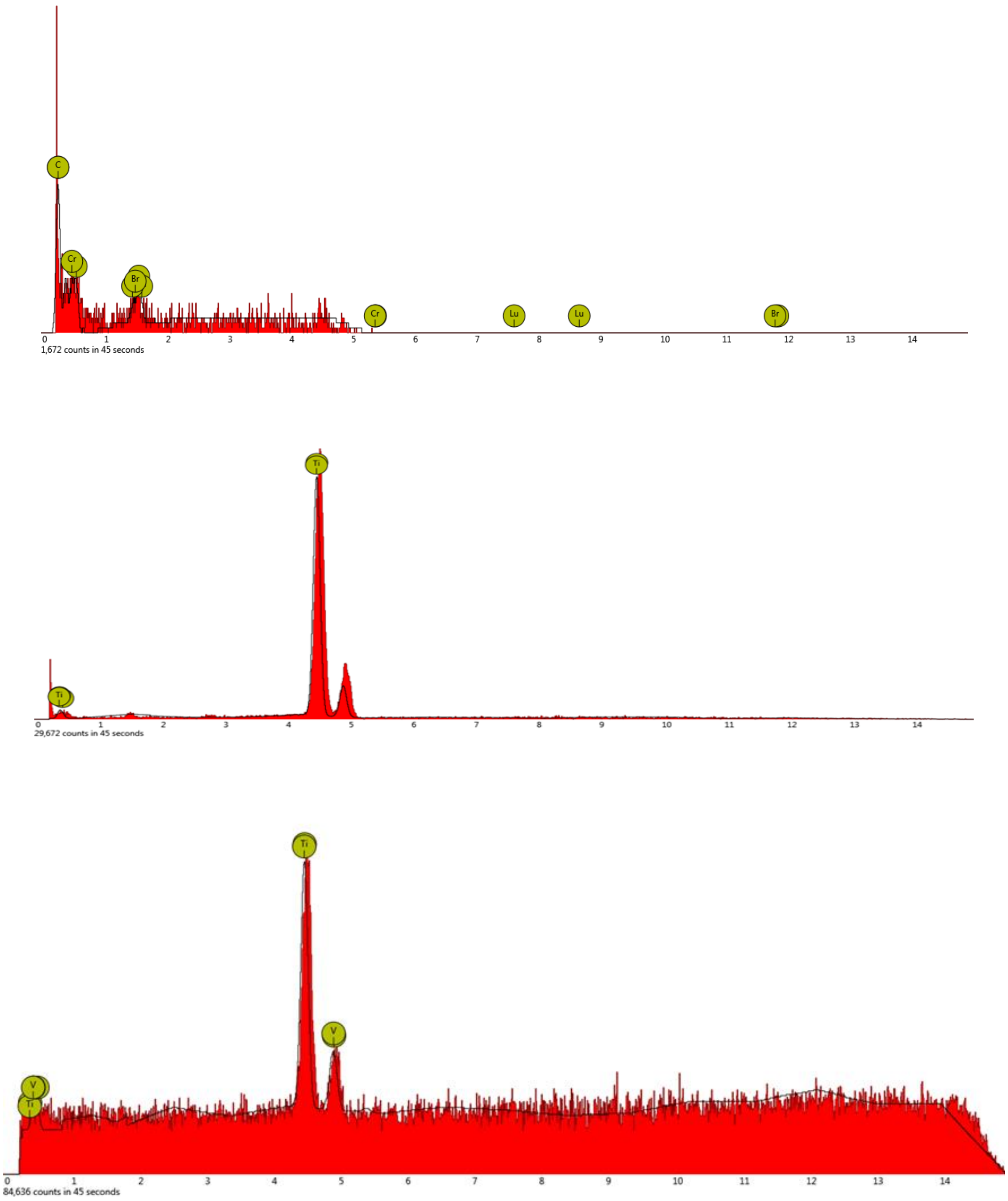


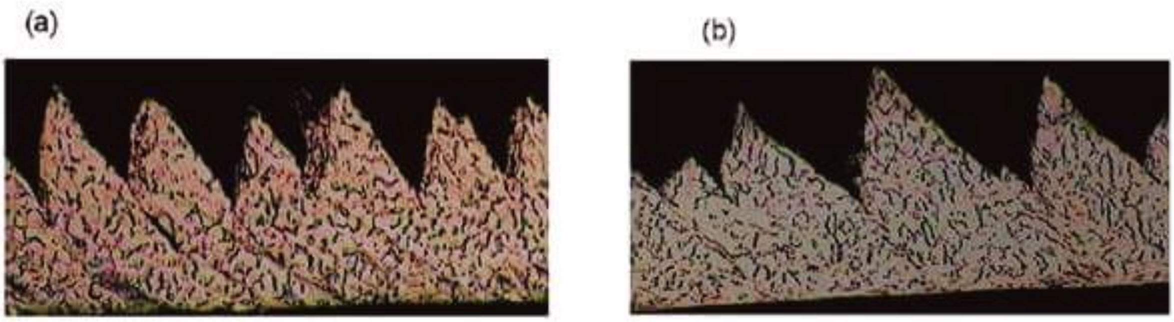
Figure 22 SEM micrographs of chip's top view for uncoated carbide inserts at 220 m/min

According to the equation stated above, the recurrence of chip serration has a straight association with the apparatus chip contact length when the cutting pace is kept consistent. In light of the Energy-dispersive X-beam spectroscopy (EDS), the weight convergence of Titanium is the most astounding when contrasted with components such as carbon, Lanthanum and vanadium.



Graph 3 EDS spectrum of chips at 120 ,160 and 240 m/min respectively

The figure introduces a term 'peak to valley (PV) extent, which depicts the consistent quality of the chip. The lower the PV extent, the steadier the chips made. For the WC–Co installs, it can be further seen from the chip regions of Fig. 23, that at 40 m/min there is despite scattering of the serrated chip parts of standard sizes with endless number of segments (six segments) within the given length of the photograph with for the most part cut down sufficiency (Fig. 23a) stood out from chips surrounded at 80 m/min (Fig. 23b), demonstrating the nonattendance of genuine chatter at the



former pace.

Fig. 23. Micrographs of chips produced at different speeds using WC–Co inserts: (a) 40 m/min, (b) 80 m/min.

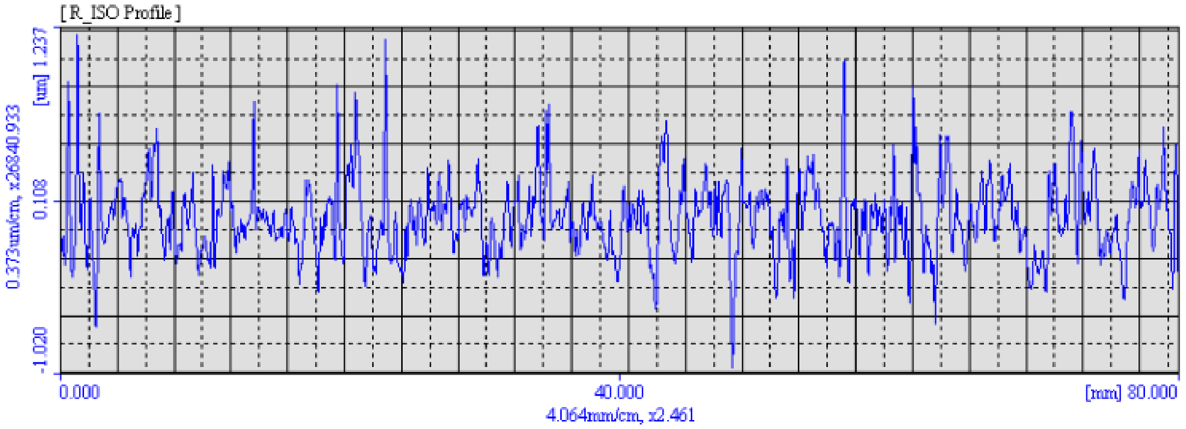
At the speed of 80 m/min the parts are seen to be greater with more diminutive number (around four broad segments) within the same length of the photograph. Two humbler segments are found to subgroup into one greater part, which is a normal for jibber jabber. The chip at 120 m/min contains again six segments within the figure with heightening of trade segments, to oblige structure vibrations at a huge segment of the chip repeat.

The recurrence of key serrated teeth is higher close to the chip's free edge and a tiny bit at once decreases with the blend or covering of parts in light of the sign from the SEM micrographs. Several fundamental serrated teeth bunch into more prominent optional serrated fragments at the free and obliged edges of the chip.

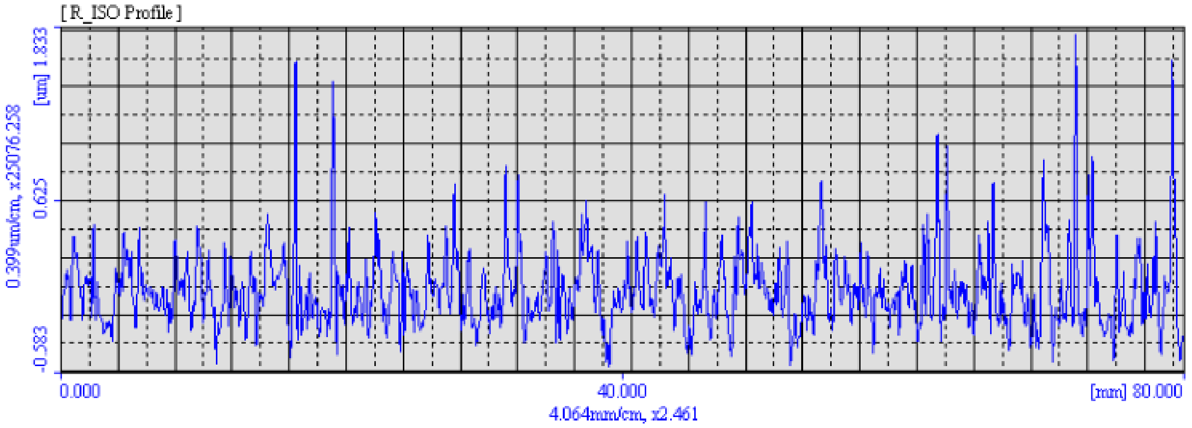
The cross-sectional conditions of the chips go anxious shape looks at to the plenitude of serrated teeth are of uniform shape, more diminutive in size and more decidedly squeezed with their higher number per given length without jibber prattle; however, under talk conditions, more unmistakable teeth with their less number and every so often with mix of then again more noticeable and more unobtrusive teeth are encased. It can along these lines be shut from Figs 23 that the serrated teeth parts size and their number per given length can give an indication of the area or nonattendance of chatter in the midst of machining. Lamella structures are the key parts for the repulsive and offensive appearance of the chip free surface. The back surface of the chip is smooth. Cutting speeds and keep up rates are urgent methodology parameters to influence the chip morphology. The tallness to-thickness level of saw-tooth chips increases with expanding cutting speeds and supports. The following vibration or jibber babble in the metal cutting framework encourages the material flight rate and recognize a crucial part in contraption wear.

4.2.2 Analysis of Surface Roughness

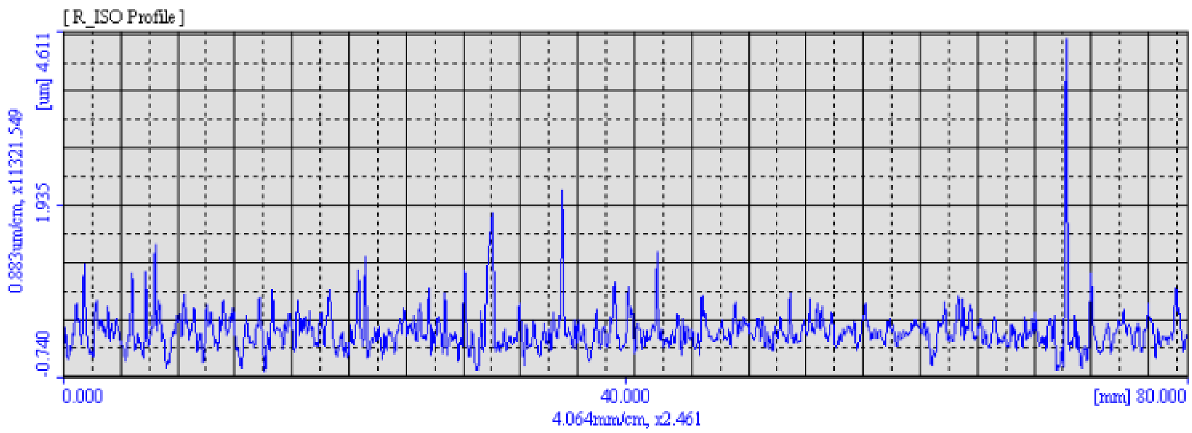
The normal distance between the top and focal pivot was used to contemplate the surface quality. To gauge the surface cruelty, the cutting length is 80mm in each test cut sample by using a 2 mm separation crosswise over stylus. Machined surface repulsiveness depends on upon a couple of components, for instance, cutting speed, manage per tooth, gadget nose traverse, nose and flank wear, jibber jabber, work-instrument material properties. In the examples of steel and distinctive metals, surface brutality decreases with the extension in cutting speed. Regardless, by virtue of titanium and its composites, surface cruelty is found to augment with the extension in cutting speed. This is related to jabber and minute gadget frustration at higher paces by virtue of uncoated carbide gadget implants.



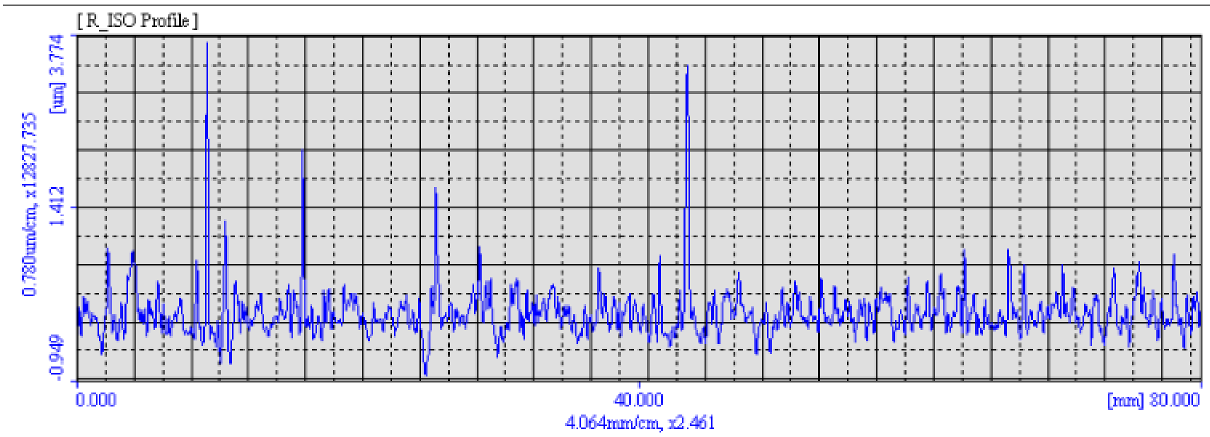
(Cutting speed 40m/min , feed 122.304 mm/min, depth of cut 0.2 mm)



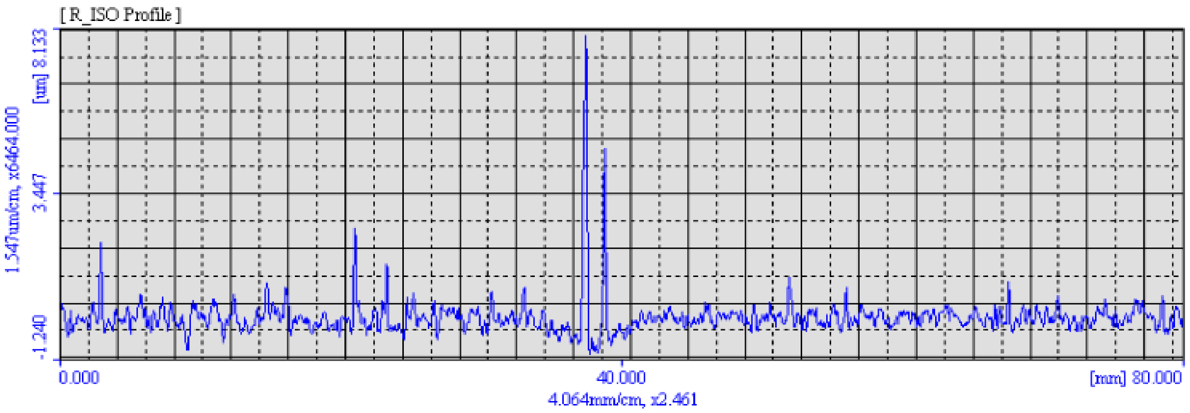
(Cutting speed 80 m/min , feed 244.420 mm/min, depth of cut 0.2 mm)



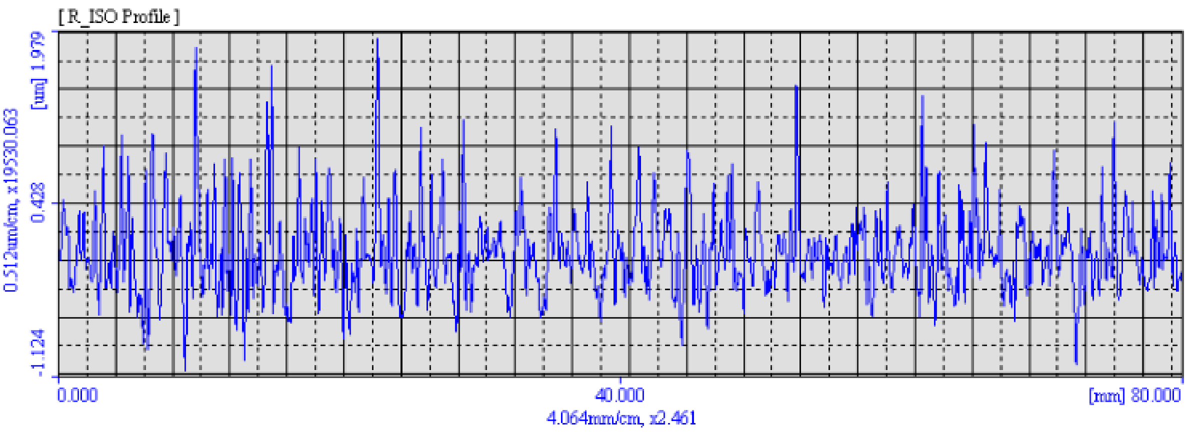
(Cutting speed 120 m/min , feed 366.72 mm/min, depth of cut 0.2 mm)



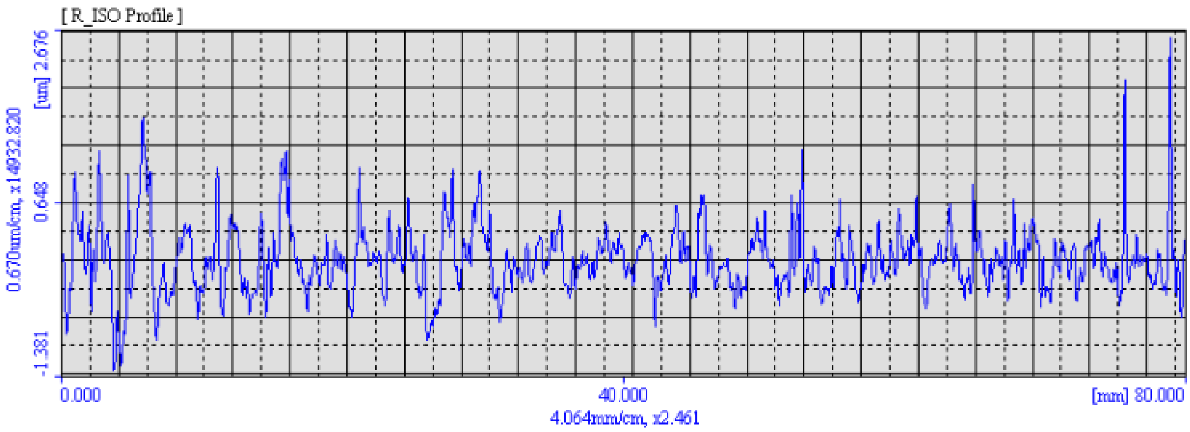
(Cutting speed 160 m/min , feed 488.832 mm/min, depth of cut 0.2 mm)



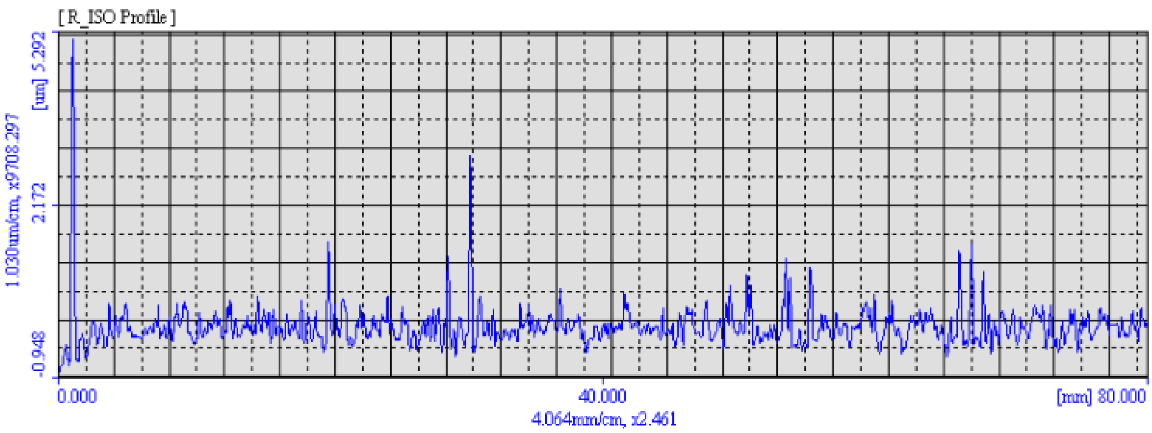
(Cutting speed 220 m/min , feed 672.193 mm/min, depth of cut 0.2 mm)



(Cutting speed 240m/min , feed 733.44 mm/min, depth of cut 0.2 mm)

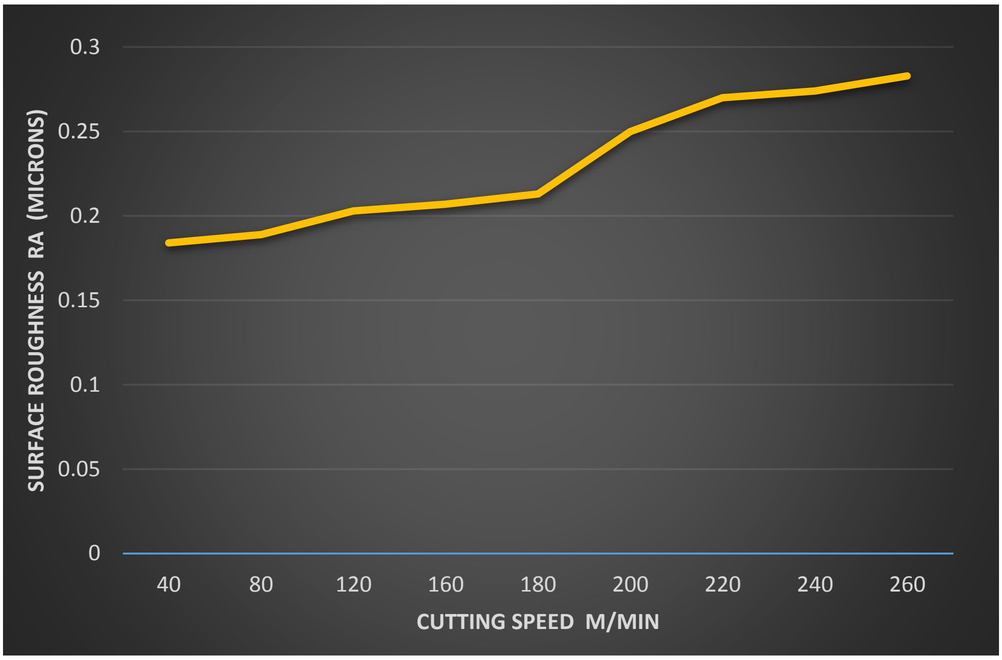


(Cutting speed 260 m/min , feed 794.50 mm/min, depth of cut 0.2 mm)



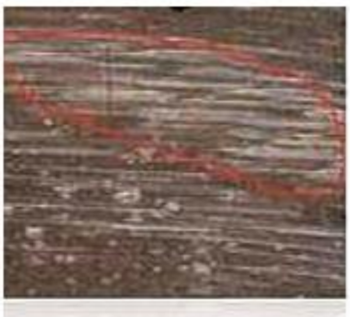
(Cutting speed 180 m/min , feed 550.10 mm/min, depth of cut 0.2 mm)

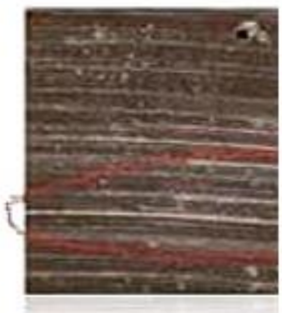
Graph 4 Surface roughness of the Titanium block after machining



Graph 5 Surface Roughness vs Cutting speed

Close investigation of the outcomes demonstrates that at a food of 122.3 mm/min yields a least harshness esteem at a cutting pace of 40m/min. on further perception it is found that at food of 366.72mm/tooth the surface harshness is less in a few districts has a greater worth at different spots because of prattle. It is likewise watched that if the food is too low then its outcome in gab development on the machined surface will prompt an uneven surface harshness esteem. In Figure 24 the highlighted range demonstrates the waviness in the surface with food of 122.3 mm/min. While 550.1 mm/min encourage indicates profound furrows in the surface irregularly. By Equation expressed over, the normal unpleasantness of the completed surface should have an exponential association with the food.





Feed=122.3mm/min **Feed = 366.72mm/min** **Feed = 550.1 mm/min**

Figure 24 Surface images of the test cut at different feeds.

Normal surface roughness is moderately low with values under 0.3 microns, up to the cutting velocity of 120 m/min, such that no crushing or cleaning would be required. Be that as it may, if the harshness quality is above 0.4 microns, then cleaning would be required for this situation however granulating might be kept away from.

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 Conclusion and Recommendation

Tool wear morphology and chip segmentation as well as surface roughness of Titanium block have been successfully investigated after end milling of titanium alloy Ti-6Al-4V using uncoated WC-Co inserts. Scraped spot/steady loss, plastic distortion and dissemination wear are the most continuous cases which are watched. Moreover, on account of medium cutting rate, low bolster and pivotal profundity of cut, scraped area/whittling down wear is happened near the rake face. At higher cutting speed and maintain, wear generally involves non-uniform wear in light of plastic distortion at the nose fragment. Mix of high cutting speed and manage altogether extend the nervousness near the nose and flank zone, creates high temperature and stimulates high wear rate. Both crucial and discretionary serrated teeth are formed in end handling of titanium compound Ti-6Al-4V using uncoated WC-Co inserts. The peak to valley extent of chip division can be familiar with inspect the constancy of a chip.

In the examination of surface roughness, it was watched that the feed of 122.304 mm/min yielded the best surface culmination to the extent Ra quality. In spite of the way that the Ra regard for lower supports was less in a couple of zones, it had zones where there indicated vibrational waviness at first look. On the other hand, higher nourishment made some high scores in the surfaces. Various chip serration frequencies were seen on individual chips. The radically changing repeat was the eventual outcome of warmth gathering and the change of chip thickness.

From the viewpoint of total volume of metal removal per tool life and surface friction made, cutting speed in the extent of 40–80 m/min may be endorsed in the midst of machining using uncoated WC–Co inserts. From this investigation it is typical that the effect of cutting pace on carbide mechanical assembly life will be extremely valuable for machining organizations especially who produce parts from Ti-compound.

It will moreover help them to pick the right cutting instrument for machining this composite. At last, this will diminish the machining time and in addition the collecting cost which will promise the sensibility in their business. Taguchi Parameter Method Design which involve central composite arrangement is also prepared to convey a more correct result. Therefore, to upgrade machining efficiency, future work ought to be conceivable by consolidating higher cutting rate in the perceptive models in perspective of what were expert in this investigation.

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