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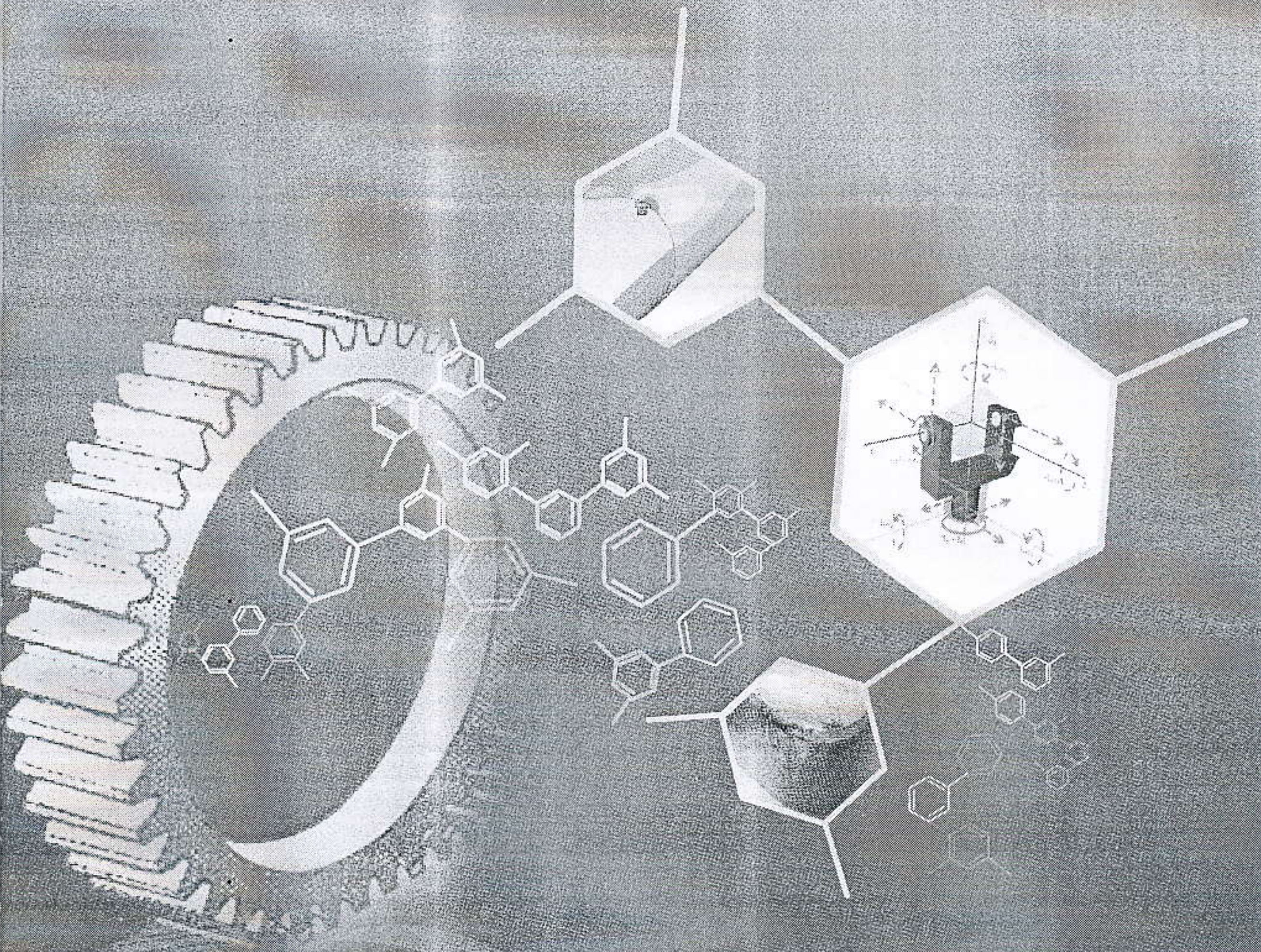

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Asian International Journal of Science and Technology in Production and Manufacturing Engineering (AIJSTPME) has intended to distribute extensive research work and develop innovative knowledge from those in wide-ranging educational, industrial, and occupational areas. Undoubtedly, shared experience and technical know-how could be applied for further enhancement of industrial production process and manufacturing. I believe that the research work in Asian International Journal of Science and Technology in Production and Manufacturing Engineering would be of high assistance to the exploration of academic members, scholars as well as researchers.

King Mongkut's University of Technology North Bangkok would like to call for your papers. I truly appreciate worldwide researchers and scholars for your comprehending of the significance of education development, particularly in science and technological fields. This would be valuable for the economic and industrial progress of the nation as well as international countries. Your contributions to the journal could be practical for extended commercial research work. On this occasion, I would like to invite all other researchers to contribute your valuable papers to Asian International Journal of Science and Technology in Production and Manufacturing Engineering (AIJSTPME).

Editor-in-Chief

Associate Prof. Suthep Butdee
Vice President for Research and Development of KMUTNB

This journal was established by the president of KMUTNB, Prof. Teravuti Boonyasopon, in 2007, in order to share new knowledge, new methods, and new findings from the experience of researchers and practitioners. As we know, Asia is one of the major areas that have produced several types of products, including industrial products, consumer products, and fashion products, for the world. However, sustainable manufacturing, with high product quality that saves on cost and protects the environment, is a concern all over the world. New technology and innovation can assist such manufacturing characteristics. In universities world-wide, lecturers, researchers, and students work cooperatively and collaboratively. Therefore, we hope that we will have lots of contributions from Asia and from all over the world so that we can share knowledge and experience and provide exchangeable knowledge. In addition, the AIJSTPME aims to establish our support for the GCMM – the Global Congress of Manufacturing and Management, which involves approximately 26 countries. Finally, I would like to thank Prof. Serge Tichkiewitch, Prof. Daniel Brissaud, Prof. Khrill Taraman, and Prof. Prasad Yalladgadda for the advice they extended to me, and our working team at KMUTNB.

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GUEST EDITOR

Prof. Prasad KDV Yarlagadda

I am delighted to write the foreword for the first volume of the Asian International Journal of Science and Technology in Production & Manufacturing Engineering (AIJSTPME) in Production & Manufacturing. This is a very important development in emerging times of shifts in manufacturing paradigms and the transfer of economic power to the Asia Pacific Region.

Outsourcing of manufacturing from Europe to Asia is on the rise, riding high on the cost differential between manpower costs in Asia and the Western Economies. The growth numbers posted by engineering and capital goods firms also reflect that Asia is the most promising destination for production outsourcing in the next decade. Foreign investments are most likely to continue not only in the engineering and manufacturing industry but also in infrastructure projects.

Asia, particularly Thailand, further assumes significance because it offers an alluring consumer market for products from high-end to low. Also, the perception is that infrastructure, tax breaks and support from the state have been generous; multinationals find it encouraging to establish production facilities in Asia. With globalization and competitive pressures, the companies in the Western economies are under price pressures and operating in volatile market environments. Companies are forced to look at cost cutting measures, improving operating efficiency and delivering results. The business landscape gives industry participants a complex equation to balance: these companies need to meet the demand of sophisticated products while enduring returns that stifle investment. As a result, the manufacturing industry has suffered a setback over the recent years in some of the world’s leading economies.

As Thailand is becoming the manufacturing hub of the world, the local manufacturing companies are realizing the need to create their own distinctive identity in front of global end-users. They no longer want to stay at the bottom of the value chain and earn a pittance as contract manufacturers for large established brands. Emboldened by overall export-led growth, several Asian original equipment manufacturers (OEMs) are now scaling up to be original design manufacturers – the highest end of the value chain. They want to nurture their own brands. For instance, Shanghai Automotive Industry Corporation (SAIC) makes cars in China under license in joint-venture with GM and Volkswagen.

Thailand companies are looking around the world for struggling, but globally recognized, brands. This is because Thai companies, while enjoying cost advantages thanks to a vast pool of cheap labor, have an image problem. Foreign consumers think of Asian goods as admirably cheap but lacking in quality. As Thai firms move up the value chain, they are keen to buy foreign brands that they can attach to their more promising products.

India is set to make better quality cars. That's because many carmakers have more than doubled their R&D spends and personnel over the past few years with in-house developed new generation engines and high-end embedded systems using Computer Aided Engineering. Indian carmakers are pulling out the stops to offer globally competitive products. American and European car makers are moving to Asia with full assurances on the standards for global quality. In a similar vein, Singapore, Taiwan and South Korea are the most attractive economic zones for high end technology output.

Asia will capture an increasing share of global manufacturing industry. The future manufacturing industry in Asia will also exhibit higher-value functions, such as research and design. In times as these, it is no wonder that a new journal is being published from Thailand where for example, Nikon, the Japanese camera giant, assembles it current range of D Series.

The urgent need to disseminate the wide body of manufacturing engineering knowledge base being generated in design, production, manufacturing and process optimization has triggered the establishment of AIJSTPME. The journal emphasizes use of engineering design and analysis and strives to maintain a balance between research and applications.

I am sure that readers from not only the scientific community but industry leaders, business managers and manufacturers will reap great benefits from the high quality papers that will be featured in AIJSTPME which seeks to highlight and introduce the rapid development in production engineering and its implicit value addition to the global market.

As President of the Global Congress on Manufacturing & Management Board, I am more pleased to note that AIJSTPME is bringing out the first volume as a special issue to commemorate the 9th Global Congress on Manufacturing & Management (GCMM2008) which was held at Gold Coast, Australia between 12-14 November 2008. The selected papers are a testimony to the whole gamut of research issues that are being addressed in production and manufacturing to create novel interfaces for the emerging economic trends in our region. I would like to congratulate, King Mongkut's University of Technology North Bangkok and Dr. Suthep Butdee and his team for their efforts in bringing such a good quality journal, which is of immediate need for Asian Manufacturing industry.

I wish AIJSTPME a long prosperous road in these exciting times.
Happy Reading!

Sincerely,

Prof. Prasad KDV Yarlagadda

President, Global Congress on Manufacturing and Management
Director, Smart Systems Research Theme
Queensland University of Technology
Brisbane, Australia

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The Effects of CBN Cutting Tool Grades on the Tool Life and Wear Mechanism When Dry Turning of Titanium Alloy

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Abstract

This study investigates the significant factors that affect the tool life, wear progression, and wear mode mechanism of the CBN cutting tool when turning Ti-6Al-4V. The effects of cutting variables are investigated by the application of partial factorial design method. The machining tests were carried out under dry cutting condition. The cutting speeds selected were 180 and 280 m min^{-1}*. The feed rates were 0.05 and 0.25 mm rev*$^{-1}$*. The experiment used T-chamfered edge. Two types of CBN grade were used in the experiment: low and high content. The study found that both of cutting speed and feed were significantly affecting the tool life. The detailed study on worn out tool using SEM revealed that the wear were occurred on both flank and rake faces of the cutting edge. The wear mechanisms such as rubbing, abrasion, adhesion, diffusion-dissolution and fracture were observed.*

***Keywords**:*

Tool life, Fractional factorial, CBN, Dry turning, Titanium 6Al-4V, Wear mechanism, Chip formation

1 INTRODUCTION

The use of titanium alloys is prevalent in most commercial and military aircrafts. Titanium is selected as materials of jet engine and airframe components due to the high strength-to-weight ratio, capable to withstand the strength at the high operating temperature and good corrosion resistance (Campbell, 2006). The relatively high cost of titanium machining has hindered wider use, for example in automotive applications. To minimize the inherent cost problem, successful applications must take advantage of the special features and characteristics of titanium. This requires a more complete understanding of titanium alloys as compared to other competing materials, including the interplay between cost, processing methods, and performance (Lutjering and Williams, 2007).

The machinability of titanium is limited by some characteristics. Some of these are low thermal conductivity, chemical reaction with the cutting tools materials, a relatively low modulus of elasticity (Ezugwu et al., 2003; Konig, 1979; Machado and Wallbank, 1990; Siekmann, 1955; Turkovich, 1982). Due to these characteristics, titanium is generally turned with uncoated carbide (Haron and Abdullah, 1999; Jawaid et al., 2000), CBN/PCBN (Brookes et al., 1991; Klocke et al., 1996; Narutaki et al., 1983) and Poly Crystalline Diamond (PCD) tools (Brookes et al., 1991). Uncoated carbide tools are suitable at low speed machining conditions while CBN/PCBN are employed at high speed machining The objective of the CBN cutting tool when turning study is to investigate the tool life and wear mechanism of Titanium 6Al-4V. The study will investigate the wear progression, the significant factors that affect the CBN tool life and the failure mode of CBN cutting tool.

2 DESIGN OF EXPERIMENT

Machinability is defined as the ease or the difficulty with which a material can be machined under a given set of cutting conditions including cutting speed, feed, and depth of cut. Machinability of a work material is accessed in terms of four factors: tool life, cutting forces, power requirements, and surface finish. It is obtained through a set combination of machining tests between material and machining parameters.

The common approach employed in manufacturing companies by many engineers last time is One-Variable-At-a-Time (OVAT). This approach will vary one variable at a time while keeping all other variables in the experiment fixed. This type of experimentation requires large resources to obtain a limited amount of information about the process. OVAT experiment often is unreliable, inefficient, time consuming and may yield false optimum condition for the process (Antony, 2003).

In spite of using OVAT, the experimenters use a statistical design of experiment. The design of experiments is widely used in experiment involving several factors where it is necessary to study the combined effect of these factors on responses. The design of experiment can significantly reduce the total number of experiment.

This study will consider the simultaneous variation of speed, feed, depth of cut and CBN content on the tool life as a response. The present study will analyze the effect of those parameters on tool life by using ANOVA. In addition to the effect of cutting parameters, the interaction among parameters also will be studied. A fractional factorial design at two-levels of half-fractions is used. A design has eight trials (Table 1).

Table 1: Level designation of different process variables

Level	**V (m/min)**	**F (mm/rev)**	**D (mm)**	**CBN content**
-1 (Low)	180	0.05	0.1	Low
1 (High)	280	0.25	0.5	High

3 EXPERIMENTAL DETAILS

3.1 Machine and cutting inserts

The machining trials were carried out on a Colchester T2 CNC Turning. A MCLNR 2020K09 tool holder was used to provide an 85^o cutting edge angle and 5^o rake angle. Two grades of CBN content investigated are KD081 and KD120 designated CNGA 120408S1020. All of the cutting experiments were conducted in dry condition. The machining was carried out at various time interval from 10 sec to 1 min and then the flank wear of the insert was recorded. Flank wear was considered as the main criteria of tool failure. The machining was terminated if the average flank wear exceed 0.30 mm or fatigue failure occured on the cutting edg.

3.2 Statistical Analysis of Tool Life

Table 4 shows the results of tool life. The results were analysed using the Design-Expert 6.0 and transformed to half-normal probability plot as in Fig 1. The figure shows that the all of the factors will affect the cutting tool life. The feed rate is the most affecting factor and followed subsequently by the cutting speed, depth of cut and CBN content.

The ANOVA was performed to calculate the main effects of cutting speed (*V*), feed rate (*f*), depth of cut (d) and CBN content, together with their two-level interaction effects on the tool life. The ANOVA output and the calculated *F* ratios are shown in Table 5 for each significant effect. The 5 per cent level was used for testing the significance of the main effects and the interaction. Table 5 shows the “Prob>F” value of all factors is less than 0.05 and among these factors; feed rate is the most significant.

Table 4: Experimental conditions and results

Run	F actors				Tool life (sec)
	Cutting speed (m/min) A	Feed rate (mm/rev) B	Cutting depth (mm) C	CBN content D	
1	180	0.05	0.1	Low	1200
2	280	0.05	0.1	High	630
3	180	0.25	0.1	High	640
4	280	0.25	0.1	Low	60
5	180	0.05	0.5	High	1200
6	280	0.05	0.5	Low	150
7	180	0.25	05	Low	60
8	280	0.25	0.5	High	36

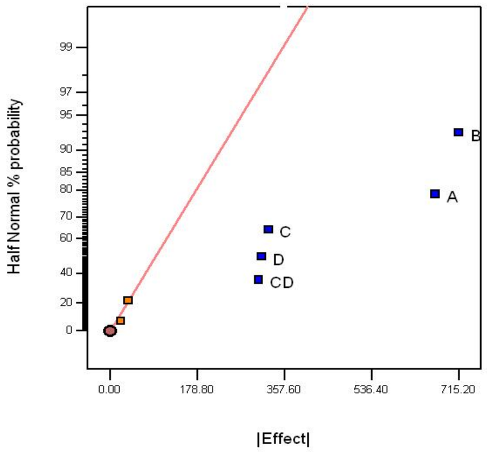


Figure 1: Half-normal probability plot of results

The two-factor interactions show a strong interaction exists between depth of cut and CBN content (CD). The tool life is long when the CBN content is kept at high level and depth of cut is kept at low level. Whereas the tool life is short when the CBN content is kept at low level and depth of cut is kept at high level. This result agreeable with Ezugwu (2005) statement that high CBN content gives longer tool lives because it can withstand the notch-wear.

Table 5: ANOVA for selected factorial model [Partial sum of squares]

Source	Sum of Squares	DF	Mean Square	F Value	Prob > F
Model	1,739,000	5	347,800	263.05	0.038
A	618,300	1	618,300	467.68	0.021
B	710,400	1	710,400	537.39	0.0019
C	146,900	1	146,900	111.11	0.0089
D	195,800	1	195,800	148.09	0.0067
CD	129,000	1	129,000	97.60	0.0101
Residual	2,644	2	1322		
Cor Total	1,741,000	7			

*5% level of significance

3.3 Tool wear mechanism

Fig 2 shows flank wear progression curves of CBN tool at various cutting conditions. The curves are generally divided into three stages: the rapid initial progress, the relatively constant progress and the rapid-to-failure progress.

At the low speed and low depth of cut, the tool worn out mostly rubbing and attrition. The wear occurred due to the depth of cut is less than the tool nose radius. At a depth of cut of 0.5 mm this wear mechanism is not obvious. Figure 3a, 3b, 4a and 4b show clearly the rubbing and attrition wear mechanism.

The wear progress tends to decrease when the cutting is continued for more than 200 seconds. The chip flowing is partially stuck at the tool edge. The stuck chip is attributed to the compressive force and increasing in temperature.

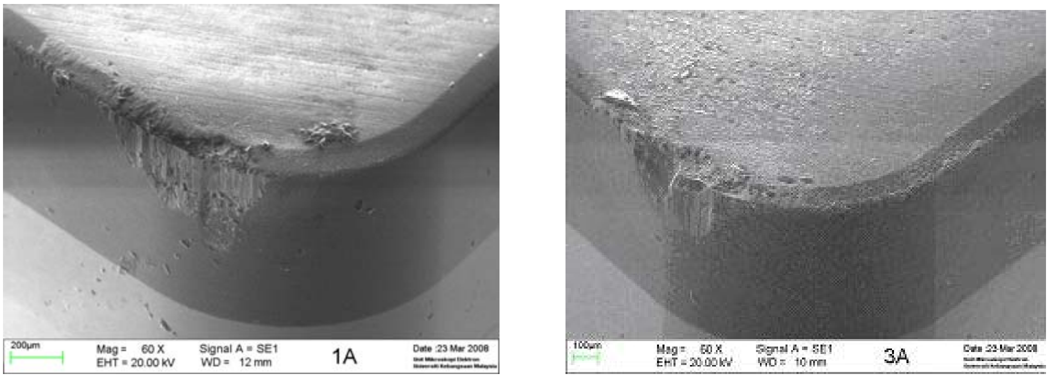
In dry environment, machining at the higher feed rate and/or at higher cutting speed will increase the temperature rapidly.

The increasing in temperature will induce the titanium to weld to the tool and formed the built-up-edge-like layer. The welded material will help the wear progression. It is very similar to built-up-edge (BUE) formation mechanism.

The blunt tool and BUE will increase the cutting force. If the welded material to the tool receives the increased stress, eventually cause the tool to fracture and the CBN material to pluck out. Figure 4a and 4b show the notch surface of CBN tool due to severe failure.

Despite of the above-mentioned mechanisms, the crater wear was occurred on CBN cutting tool. The tendency of crater wear on titanium alloy is stronger because occurrence of the CBN is classified as the cutting tool wears mainly by adhesion (Narutaki and Yamane, 1993)

The compressive stress is considered small when chip is flowing on tool rake face, even though the friction forces exist. This caused chip to rub and scrap the tool material. The temperature of chip formation is more than 1000^{o}C. At an elevated temperature, the titanium react more to certain tool material. The combination both of friction force and high temperature caused the material to be welded to the tool. The dissolution and diffusion phenomena occurred at the welded cutting tool and material. The dissolution-diffusion mechanism caused the crater formation in the chamfered edge land (Min and



(a) (b)

Figure 3: SEM micrograph of CBN tools while machining Ti-6Al-4V at cutting speed 180 m/min, feed rate 0.05 mm/rev (a) depth of cut 0.1 mm, (b) depth of cut 0.5 mm.

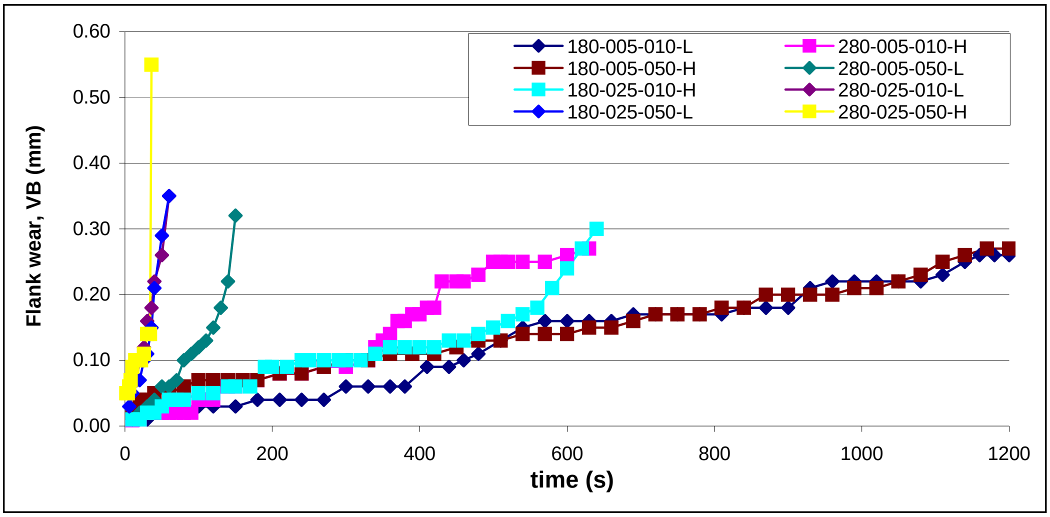
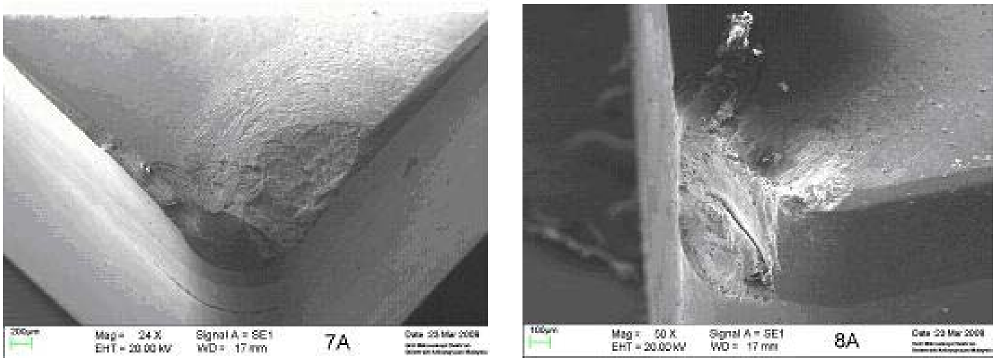


Figure 2: Flank wear curves at different machining conditions



(a) (b)

Figure 4: SEM micrograph of CBN tools while machining Ti-6Al-4V at cutting speed 280 m/min and feed rate 0.25 mm/rev (a) at depth of cut 0.1 mm, (b) at depth of cut 0.5 mm

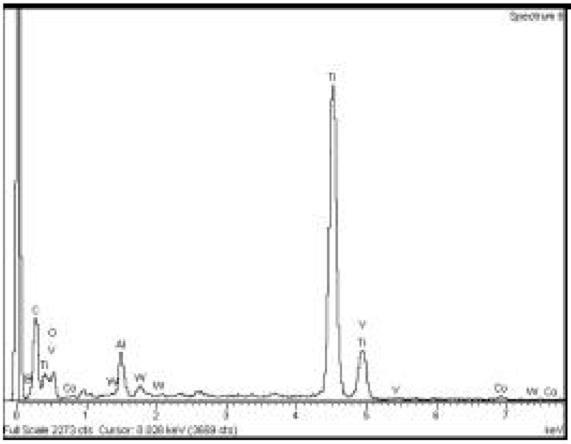


Figure 5: EDAX analysis of CBN insert tool at 280 m/min, 0.25 mm/rev and 0.1 mm.

Youzhen 1988). Figure 4a and 4b show the crater obviously. EDAX analysis also support that the dissolution-diffusion mechanism occurred at the cutting edge and crater (Figure 5).

3.4 Metallurgical aspects

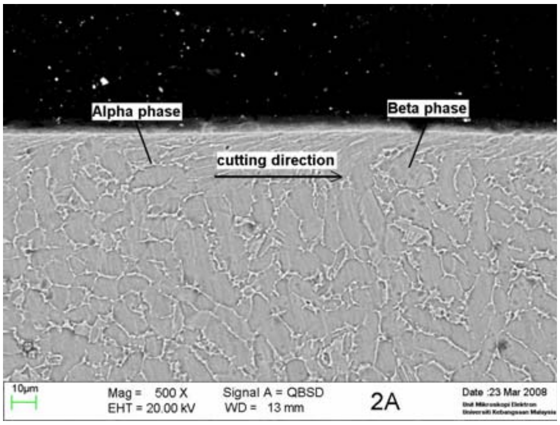


Figure 6: SEM micrograph of machined surface

Figure 6 shows the SEM micrograph of machined surface at a cutting speed of 280 m/min, feed rate of 0.05 mm/rev and depth of cut of 0.1 mm. The change of grain orientation occurred because of tool compressive force. The grain was elongated in cutting direction and caused the thinner shape. Even though the grain shape changed but the white layer does not exist in the machined surface. Therefore, both lower speed and higher speed can be applied in finish turning of Ti-6Al-4V.

4 CONCLUSIONS

In this work, it has been shown that partial factorial design of experiments can be used in analyzing the effect of CBN cutting tool grades to tool life when turning Titanium 6Al-4V. The design is very helpful in the running of expensive cutting tool-material combinations. The feed rate is found to be the most significant factor to tool life, followed by cutting speed, depth of cut and CBN grades. At the same cutting speed and feed rate, the lower CBN grade is more affected by changing the depth of cut.

CBN tool shows three stages of wear progression: the rapid initial progress, the relatively constant progress and the rapid-to-failure progress. The wear mechanisms present were rubbing, abrasion, adhesion, diffusion-dissolution, and fracture. The cutting speed induced attrition wears, while fracture was due to high depth of cut. Whereas diffusion-dissolution was induced by increasing temperature during the turning operation.

5 ACKNOWLEDGEMENTS

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