Effect of High Speed Machining on the Turning Aluminum Alloy6061 of the Integrity Coated TiAlN/TiN Cutting Tool Carbide

Sunarto and Razali
Department of Mechanical Engineering, Politeknik Negeri Bengkalis, Jalan Bathin Alam, Bengkalis, Indonesia

Keywords: Cutting Speed (*Vc*), Cutting Tools, Coating Materials, Titanium.

Abstract: Improved performance of carbide cutting tools that are widely used in the field of the metal cutting machining process is done by coating the base material of the cutting tool with the coating material. From the results of previous research, it was concluded that cutting tools coated with Titanium Aluminum Nitride and Titanium Nitride (TiAlN/TiN) have toughness when cutting stainless steel. Other studies have concluded that coating materials do not work properly when used to cut nonferrous metal alloys (Titanium). The integrity of the coating element is very closely related to the mechanism of cutting tool wear in the form of chemical reactions. The response between TiAlN/TiN coating material and the cut base material of Aluminum alloy 6061 became the subject to be observed in this study. The cutting method is divided into three categories, namely low with cutting speed Vc 800 m/min, medium with cutting speed Vc 1000 m/min, and high with cutting speed of 1200 m/min. The results of the study concluded that each cutting condition specified for each TiAlN/TiN coating element observation point has not been found.

1 INTRODUCTION

Cutting speed above ≥ 1000 m/min for cutting aluminum alloy material type is categorized in high speed machining (Schulz & Moriwaki, 1992). The impact arising from high cutting speed is the increasing cutting temperature (Schey, 2000) (Abhang, L.B., et al, 2010) (Nouari, et al, 2003). According to Rochim (1993), the result of oxidation at high cutting speeds resulted in decreased cutting tool carbide resistance. Efforts are made to improve the toughness of cutting tool carbide (WC+Co) by coating the base material of the cutting tool using coating materials including Titanium Aluminum Nitride (TiAlN) and Titanium Nitride (TiN). It is expected that the coating can serve as a solid lubricant and as a sealing wall between the base material of the cutting tool against the workpiece, thus the rate of damage to the cutting tool can be suppressed. According to Yin Fei, et al, (2005) multilayer layers made on layered cutting tool carbide (TiAlN/TiN) have high hardness, are wear-resistant, more resilient in cutting when compared to coatings made of monolayers (TiAlN), this study was conducted on the lathe using stainless steel material with a cuttingspeed (*Vc*) of 220 m/min, feeding motion (*f*) 0.2 mm /round and cutting depth (*a*) 0.2 mm. The performance of the Titanium Nitride (TiN) coating found in the cutting. tool is not by its function when cutting the Alloy Titanium Ti-6246 at a cutting speed milling operation (*Vc*) of 55 m/min, feeding motion (*f*) 0.1 mm/tooth and feeding depth (*a*) 2 mm were found to have an exfoliating coating at the beginning of the initial wear process and were concluded as a result of high reactivity to Titanium Ti-6246 during the cutting process (S.Sharif, et al. 2008). Other findings relating to the exfoliation of coatings against cutting tool base materials at the beginning of cutting were also presented by G.A. Ibrahim, et al, (2010) on Titanium alloy material with lathe operation with cutting speed (*Vc*) off 55 m/min, feeding motion (*f*) 0.15 mm/round and cut depth (*a*) 0.10 mm.

To see the integrity of coating materials in this study the authors will conduct experiments that are cutting Aluminum alloy 6061 using layered cutting tool carbide of Titanium Aluminum Nitride and Titanium Nitride (TiAlN/TiN) at cutting speeds of 800, 1000, and 1200 m/min in cutting conditions without the use of coolant.

1.1 High-speed Machining

High-Speed Machining is one of today's modern technologies, where in comparison with conventional

Sunarto, . and Razali, .
Effect of High Speed Machining on the Turning Aluminum Alloy 6061 of the Integrity Coated TiAlN/TiN Cutting Tool Carbide.
DOI: 10.5220/0010946900003260
In *Proceedings of the 4th International Conference on Applied Science and Technology on Engineering Science (iCAST-ES 2021)*, pages 423-428
ISBN: 978-989-758-615-6; ISSN: 2975-8246

cutting processes it is possible to improve the efficiency, accuracy, and quality of the workpiece and at the same time can lower the costs and machining times. Schulz (1992) says that the process of high-speed machining is determined based on the type of material used as shown in Figure 1.

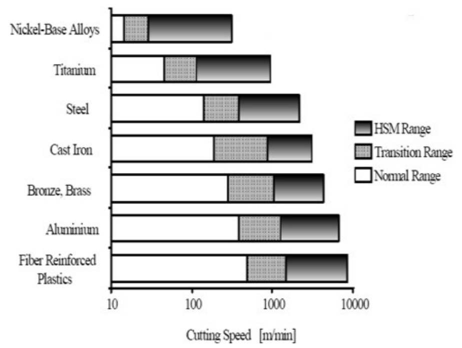

Figure 1: Cutting Speed at High-Speed Processes.

1.2 Cutting Temperature

Because the cutting area continues to move on the workpiece, the heating rate in front of the cutting tool is relatively small, and at least at high cutting speeds, most of the heat (more than 80%) is carried away by the chip. Nevertheless, the cutting tool continuously intersects with the chip since there is no heat sealing layer, the side face of the cutting tool becomes hot. Friction on the face of the cut side (deformation in the cutting area of the secondary) is also the cause of heating. Detailed calculation results show that the maximum temperature occurs on the face of the cut side which is located a bit far from the end of the cutting tool before the chip is lifted. As expected, the maximum temperature (*Tmax*) and average interface temperature (*Tint*) rise as the cutting speed increases, as shown in Figure 2.

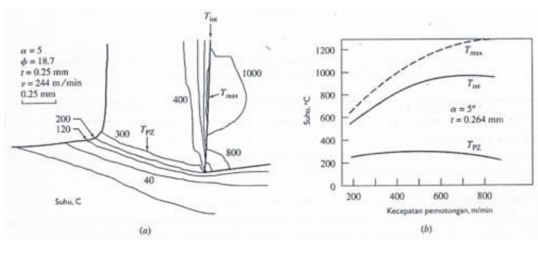

Figure 2: (a) Calculation of temperature distribution inchip and cutting tools, (b) Temperature variation with cutting speed during AISI 1016 steel cutting with carbide cut chisel.

According to Abhang L.B et al, (2010) in their research on the lathe process using alloy steel workpieces with EN-31 series temperature increase in cutting tool is the effect of cutting conditions. More clearly they elaborate as follows:

1. Result of cutting speed (*Vc*) The cutting speed greatly affects the increase in cutting temperature. They further explained that the increasing speed of friction cutting will increase, which will lead to an increase in temperature in the cutting zone.
2. As a result of the motion of eating (f) With increased feeding motion (*f*) affecting the growl, causing increasedfriction and causing a rise in cutting temperatures, this is as reported by Shaw (1984), Stephenson (1992).
3. Resulting from cutting depth (*a*) Changes in cutting temperature are recorded in the cutting zone as a function ofcutting depth for different cutting speeds and feeding motions with a constant cuttingtool radius (0.4mm).

1.3 Mecanishm Cutting Tool Wear

One of the mechanisms of cutting tool wear is a chemical reaction. Two surfaces that rub against each other with considerable pressure along with an active chemical environment (air or coolant witha certain composition) can cause interaction between the cutting toolmaterial and the workpiece. The newly formed workpiece material surface (the sultry surface and the cut workpiece surface) are so chemically active that it is easy to react again and stick to the cutting tool surface. At low cutting speeds, oxygenin the air in the gaps between the cutting tool with a growl or workpiece has theopportunity to react with the material of theworkpiece to reduce the degree of unification with the surface of the cutting tool. As a result, the contact area where theshift between the cutting tool and the chip/workpiece will be wider so that the wear and tear process due to friction will occur faster. To observe damage/wear of the cutting tool coating as a result of chemical reactions used Microscope Elekron Scanning and Energy Dispersive X-Ray Spectroscopy (SEM-EDS). SEM- EDS is a tool that can provide direct information about the topography (texture of the sample surface), morphology (shape and size), composition (constituent elements of the sample), as well as crystallography information (atomic arrangement of the sample preparation).

Ginting (2006) damage to the coating element in the form of coating delamination is the occurrence of loss of cutting tool in the form of layers from surface of the cutting tool. The exfoliation of the coating can be seen in Figure 3.

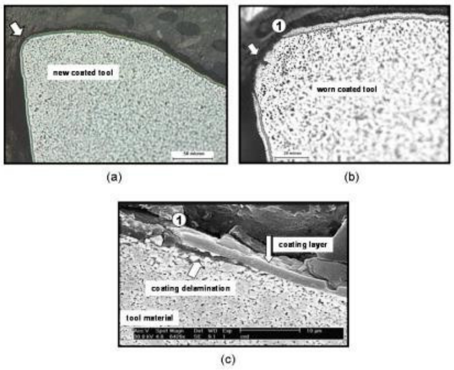

Figure 3: Coating Delamination Cutting Tool.

According to Nouari and Ginting (2006), in the case of cutting tool coated exfoliation occurs with the beginning of micro-cracks that take place inside the coating layer and then followed by the rapid removal of the layer material. In general, the investigation of coating peeling is not an easy job, it is due to the complex interaction between several factors that play a role in exfoliation such as Dry Machining Operation Environment (DMOE), the nature of coating materials, and the interaction between cutting tool, layers, and workpieces.

2 RESEARCH METHOD

Research on the effect of high cutting speed on the turning of aluminum 6061 on the integrity of cutting tool carbide coated TiAlN/TiN material was conducted experimentally. Observing the integrity of the coating material is done by dividing it into three cutting conditions, namely low, medium and high cutting conditions.

a) Data retrieval under low category cutting conditions is carried out with the following steps:
   1) Cutting Aluminum alloy 6061 with cutting speed (*Vc*) of 800 m/min, feeding motion (*f*) 0.2 mm/round, cutting depth (*a*) 1.5 mm, and cutting time length (*tc*) more than 6 minutes (ISO 3685, 1977).
   2) The integrity of coating materials is detected using Energy Dispersive X-Ray Spectroscopy (EDS).

b) Data retrieval in category medium conditions is being done with the following steps:
   1) Cutting Aluminum alloy 6061 with cutting speed (*Vc*) of 1000 m/min, feeding motion (*f*) 0.2 mm/round, cutting depth (*a*) 1.5 mm, and cutting time (*tc*) more than 6 minutes (ISO 3685, 1977).
   2) The integrity of coating materials is detected using Energy Dispersive X-Ray Spectroscopy (EDS).

c) Data retrieval under high category cutting conditions is carried out with the following steps:
   1) Cutting Aluminum alloy 6061 with cutting speed (*Vc*) of 1200 m/min, feeding motion (*f*) 0.2 mm/round, cutting depth (*a*) 1.5 mm, and cutting time (*tc*) longer than 6 minutes (ISO 3685, 1977).
   2) The integrity of coating materials is detected using Energy Dispersive X-Ray Spectroscopy (EDS).

3 RESULT AND DISCUSION

3.1 Low Category Cutting

Detection results using Energy Dispersive X-Ray Spectroscopy (EDS) after cutting Aluminum alloy 6061 in the low category at the 7 spectrum observation point were not found elements of TiAlN/TiN coating material and the discovery of Tungsten element (W) by 52.20% and Cobalt element (Co) by 3.92%. Tungsten (W) and Cobalt (Co) are the basic ingredients of cutting tools carbide (WC+Co). An aluminum element of 14.54% is indicated as a chip of a cut workpiece attached to the surface of the cutting tool. Meanwhile, at the observation point of spectrum 6 also not found elements of TiAlN/TiN coating material and the discovery of tungsten element (W) of 60.72 % and cobalt element (Co) of 4.06% more than at the observation point of spectrum 7.

Based on the above EDS results can be said that at the speed of cutting speed 800 m/min coating material elements namely Titanium Aluminum Nitride (TiAlN) and Titanium Nitride (TiN) has not been found. The EDS results can be seen more clearly in Figure 4 and Figure 5:

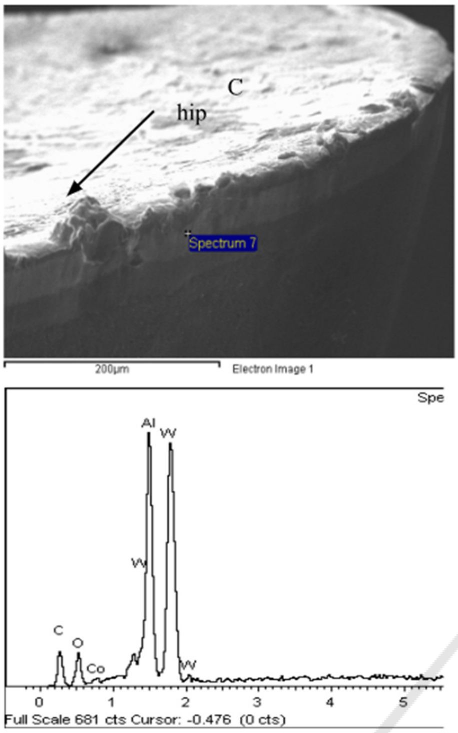

Figure 4: Observation Points on Spectrum 7.

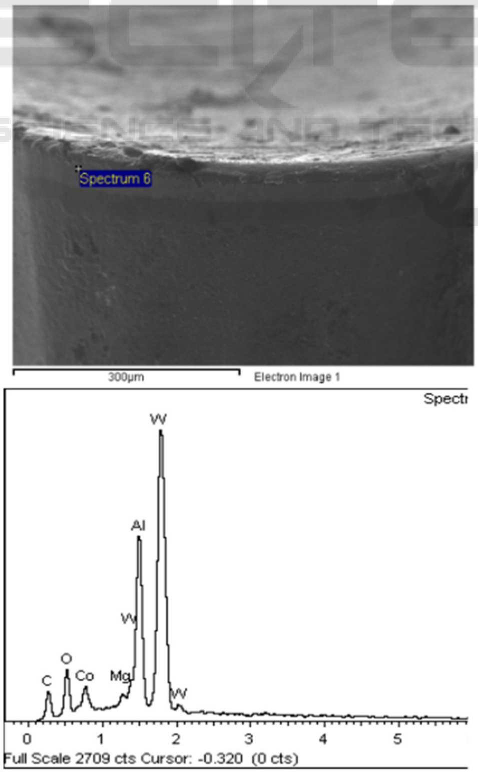

Figure 5: Observation Points on Spectrum 6.

3.2 Medium Category Cutting

Detection results using Energy Dispersive X-Ray Spectroscopy (EDS) after cutting Aluminum alloy 6061 in the medium category at the observation point of spectrum 1 were not found elements of TiAlN/TiN coating material and the discovery of Tungsten element (W) by 82.85% and Cobalt element (Co) by 4.29%.On the spectrum of 4 EDS results were alsonot found elements of coating materials(TiAlN/TiN) and the discovery of tungstenelement (W) by 79.09% and Cobalt element (Co) by 3.87%. Detection results at cutting speeds of 1000 m/min greater Tungsten element (W) and Cobalt (Co) element were found when compared to cutting speeds of 800 m/min. It can be saidthat at a cutting speed of 1000 m/min the TiAlN/TiN coating material element disappears faster when compared to thecutting speed of 800 m/min. The EDS results can be seen more clearly in Figure 6and Figure 7:

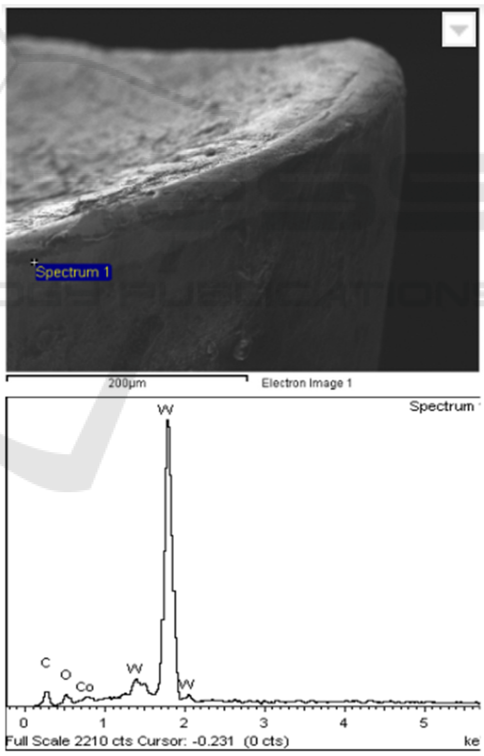

Figure 6: Observation Points on Spectrum 1.

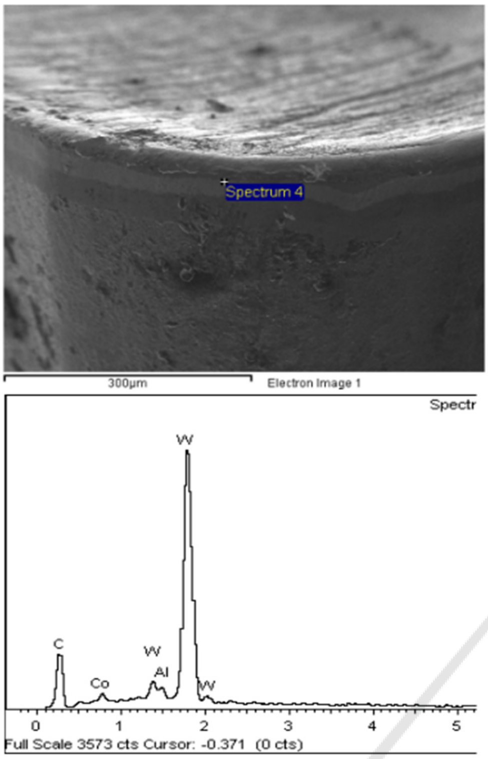

Figure 7: Observation Points on Spectrum 4.

3.3 High Category Cutting

Detection results on the spectrum 8 is dominatedby the basic elements of the cutting tool cobalt (Co) 5.55 % and Wolfram (W) 64.01 %. No Titanium Aluminum Nitride (TiAlN) and Titanium Nitride (TiN) were found to have been lost in 6 minutes cutting time at a cutting speed of 1200 m/min. Observation points on the spectrum 4 were alsofound the basic elements of the chisel cobalt (Co) 4.91% and Tungsten (W) 64.01%. Found aluminumelement (Al) by 8.84% is estimated to be a chip attached to the surface of the chisel. The EDS resultscan be seen more clearly in Figure 8 and Figure 9:

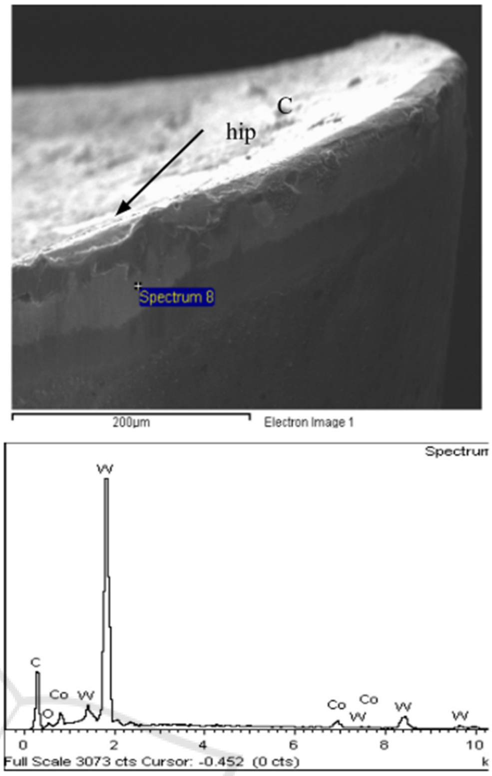

Figure 8: Observation Points on Spectrum 8.

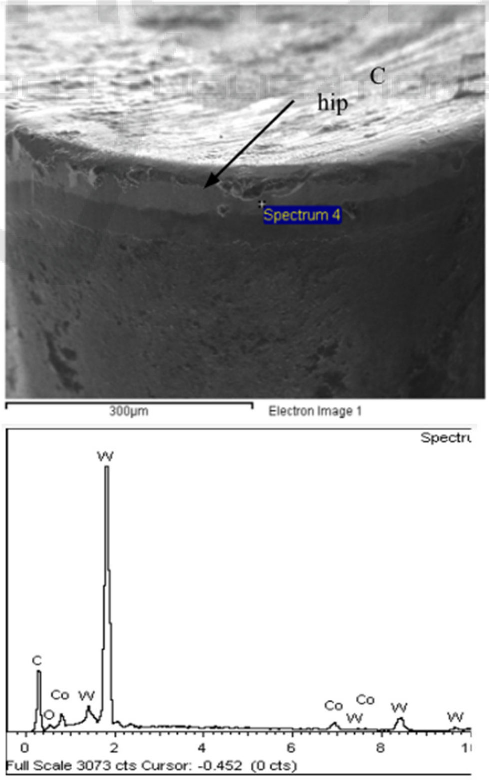

Figure 9: Observation Points on Spectrum 4.

4 CONCLUSION

The result of cutting Aluminum alloy 6061 at high cutting speed in the turning process can be concluded as follows:

1. At the cutting speed of the low category, namely800 m/min at observation points 6 and 7, no TiAlN/TiN coating material was found, the average element of Wolfram (W) was 56.46% and Cobalt (Co) was 3.99 % which is the base material for cutting tool.
2. At the cutting speed of the medium category, namely 1000 m/min, observation points 1 and 4 did not find TiAlN/TiN coating material elements, the average Wolfram element was 80.97% and Cobalt was 8.16%. The basic elements in the form of Wolfram and Cobalt were found more than at a cutting speed of 800 m/min.
3. At the cutting speed of the high category, namely 1200 m/min, observation points 8 and 4, TiAlN/TiN coating materials were not found, Wolfram elements were found on average 64% and Cobalt was 5.23%. In the three low, medium and high cutting conditions at several observation points the presence/integrity of TiAlN and TiN as cutting tool coating materials was not found.

REFERENCES

Abhang, L.B., 2010, Chip-Tool Interface Temperature Prediction Model for Turning Process*. International Journal of Engineering Science and Technology*, Vol. 2(4), 2010, 382-393.

ISO 3685 Second Edition 1993.

G.A. Ibrahim, C.H., Che Haron, and J.A. Ghani., 2006, *Tool Wear Mechanisme in Continuous Cutting of Difficult to Cut Material Under Dry Machining*. Journal Advanced Materials Research (Volumes 126 – 128).

Nouari M. dan Ginting A., 2006, *Wear Characteristics and Ferformance of Multi-layer CVD-Coated Alloyed Carbide Tool in Dry End Milling of Titanium Alloy*. Surface Coating Technology. 200:5663-5676.

Rochim, Taufiq., 1993, *Teori & Teknologi Proses Pemesinan.*Higher Education Development Support Project. Jakarta.

S. Sharif, Mohruni A. S., Jawaid A., 2008, *FaceMilling of Titanium Alloy Ti-62 using PVD-TiN Coated Carbide Tools.* Advance in Manufacturing And Industrial Engineering. Universiti Teknologi Malaysia.

Schulz, H. dan Moriwaki T., 1992, *High Speed Machining.*Annals of the CIRP.

Schey, A. dan John., 2000, *Introduction to Manufacturing Process*. 3 rd Ed. Mc/ Graw – Hill Book Co.

Yin Fei, WU En xi, Chen Li, , Wang Xiu quan., 2005, *Microstructure and Physical Properties of PVD TiAlN/TiN Multilayer Coating*. Trans. Nonferrous Met. Soc. China. Vol. 15.