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BURR FORMATION ANALYSIS WHEN MICRO MILLING Ti-6Al-4V ELI USING END MILL CARBIDE INSERT

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ABSTRACT

One of the most popular titanium alloys used in manufacturing industries is titanium alloys with 6% of aluminium, 4% of vanadium and Extra Low Interstitial and also known as Ti6Al4V ELI. Titanium alloy is developed widely in many manufacturing industries because of its prominent characteristics namely high strength-to-weight ratio and good biocompatibility with human body. This research aims to analyze burr mechanism of titanium 6Al 4V ELI which was machined by using micro milling method in dry cutting condition. Machining trials were conducted at selected condition of milling parameters which are spindle speed of 10.000 and 15.000 rpm, feed rate of 0.001 and 0.005 mm/rev, depth of cut of 100 and 150 µm and diameter of cutting tool of 1 and 2 mm. The form and type of burr were observed under Scanning Electromagnetic Microscope (SEM) for each machining process according to the selected parameters. This method was done to identify the burr at both sides (left and right) of cutting groove. The results showed that the diameter of cutting tool was the most significant factor effected on burr formation. The use of bigger diameter of cutting tool produced serrated, smaller and shorter burr formation. Machining at 1 mm of diameter of tool and depth of cut of 150 µm resulted long formation of burr and tight serrated. Contrary, the use of cutting tool diameter of 2 mm and depth of cut of 100 µm generated short and slight burr formation.

1. **Introduction**

Titanium and titanium alloys are materials which are worldwide developed in many manufacturing industries. One of them is titanium alloy consist of 6% aluminium, 4% vanadium and Extra Low Interstitial which is also known as Ti6Al4V ELI. Now, this titanium alloy is more developed because of its prominent characteristics. Those characteristics are high strength-to-weight ratio, resistance to corrosion at high temperature, and good biocompatibility. Therefore, the titanium alloy has been used in many areas such as electronic industries, aerospace material, oil exploration and biomedical field [1]. However, titanium alloys have also some drawbacks, such as are poor thermal conductivity, low modulus elasticity and highly reactive with other materials. Low thermal conductivity causes high temperature generated during machining at the contact area between cutting tool and workpiece material. It can cause premature fracture and chipping on the cutting edge of the cutting tool. Low modulus elasticity tends to difficult to cut and results poor machined surface quality. Furthermore, titanium alloy reacts easily with cutting tool material and tends to build-up-edge and welded at the cutting edge [2]. Therefore, titanium alloys are categorized as difficult-to-cut material. Before surface damages occurred on the machined surface, burr formation took place at both sides of grooved path. The burr is not only can cause surface damages but also generates microstructure alterations, thus effecting the machined surface quality [3]. Burr formation during milling process was influenced by machining parameters such as spindle speed of tool, feed rate, depth of cut, and machining conditions [1]. During metal cutting process always followed by some material welded at the workpiece and cutting tool. Severe welded material can be generated at both sides of groove path for ductile material [4].
Titanium is ductile material that has low modulus of elasticity, so that it is categorized as difficult-to-cut material. Machining with micro scale encounters a serious problem in producing minimize errors, geometry precision, surface quality and other damages. Therefore, investigation of burr formation and its mechanism were need so that the burr formation can be minimized. Considering on previous researchers that in term of burr formation and mechanism during machining at micro scale. They are four types of burr formation. It can be categorized namely rollover burr, tear burr, cut-off burr and Poisson burr. Every category has a specific characteristic and can be found at different condition of machining. The factor of burr formation depends on the ratio of uncut chip thickness and radius of cutting edge [5]. The cutting tool edge plays an important role to reduce the height of Poisson burr. The minimum exit burr can be obtained if the uncut of chip thickness is equal to cutting edge radius. The burr can cause serious problem during machining mainly in machining of titanium alloys. In the end of milling process, the entrance burrs, exit burrs, top burrs and side burrs are created differently based on cutting parameters applied. Indeed, the burrs are very difficult to remove and the mostly affected on the surface quality, thus further investigation on this problem needs to be carried out [6]-[7].

2. Experimental Menthod

The material used in this experiment is the titanium alloy with 6% aluminium 4% vanadium and extra low interstitial with is lamella α phase and surrounded by β in a grain boundary. The extra low interstitial means that the alloy contents low oxygen and hydrogen element. The machining trials were done by using end mill cutting tools with diameter of 1 and 2 mm. The micro-milling used in this experiment is a CNC machine micro-milling with three axis travels and maximum spindle speed of 20.000 rpm. The type of cutting tool used this trial is uncoated carbide. The carbide tool has high resistant to abrasive wear and can maintain high strength at high temperature. Analysis of burr formation are based on the burr size, burr high and burr type. Burr mechanism and formation were observed using SEM to analyse the burr produced visually.
Experimental design used in this experiment was a full factorial with four factors and two levels each. There are 16 samples of experiments. Every sample was machined by the CNC micro milling which is controlled by Fanuc control system, thereafter the micro end-mill carbide tools are implemented at different setting cutting parameters. Effect of cutting parameter and size of cutting tool diameter are also investigated. Detail selected parameters used in this experiment as shown in Table 1.

Table 1: *Setting cutting parameters used in the experiment consist of four factors and two levels.*

No	Tool diameter (mm)	Spindle speed (rpm)	Feed rate (mm/rev)	Depth of cut (µm)
1	1	10.000	0,001	100
2	2	15.000	0,005	150

3. Results And Discussions

Figure 2 shows burr obtained on machined surface for machining at spindle speed of 15.000 rpm, depth of cut of 150 µm and using diameter tool of 2 mm. Figure 2(a), machining at feed rate of 0.001 mm/rev whereas Figure 2(b) machining at feed rate of 0.005 mm/rev. It can be seen that the feed rate contributes significantly on the burr generated. The burr generated during machining at feed rate of 0.005 and 0.001 mm/rev can be seen very obvious. Machining at feed rate of 0.001 mm/rev produced less and shorter burr compare to machining at feed rate 0.005 mm/rev. Whereby machining at feed rate of 0.005 mm/rev, produced more and longer burr. In this case, the burr happens at both side of cutting directions. However, each side of groove shows different burr generated. Different size and form of burr were due to different cutting mechanism. At right side, cutting mechanism is down milling whereas at left side is up milling. Between up milling and down milling, there is a different direction of cutting force, thus for burr was observed for the up milling (left side). As stated by previous researcher that the burr size produced during machining depends on the cutting parameters and mode of cutting [4],[8]. They also observed the different characteristics of burr generated along the groove path which are burr width, burr high and burr angle. To analyse an angle, the sample was mounted by using mounting powder and polishing until plate surface. The burr produced at left side was more than at right side, because at left side of channel occurred up milling mechanism [9].

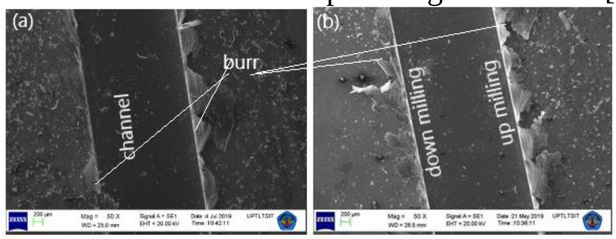

Figure 2: *Burr performance at two sides groove channel under Scanning electronic magnetic at spindle speed of 15.000 rpm, depth of cut of 150 µm and diameter of tool of 2 mm under SEM: (a) at feed rate of 0,001 mm/rev and (b) feed rate of 0,005 mm/rev.*

Figure 3 shows burr generated after micro milling using carbide insert at different tool diameter. The cutting was performed at spindle speed of 10.000 rpm, depth of cut of 100 µm and feed rate of 0.001 mm/rev. Figure 4(a) and 4(b) are machining at depth of cut of 1mm 2 mm respectively. From the figure, it can be seen that the size of diameter had significant effect on the burr formation. Smaller diameter of tool produced more burr. The size of burr generated for milling using smaller diameter are bigger. This difference, might be due to the high heat generated and high cutting force during cutting took place [10].

There are also significant difference between the burr generated at each side of the groove path. According to Schueler et.al [11] during micro machining of titanium alloy, the burr formation depends on the manufacturing process, shape, formation mechanism and material properties. The different burr formation on the both side of the groove might be due to effect of down and up milling mechanism. During machining material titanium, the compressive stress pushes the material toward the free surface and generates larger burr. Ductile material like titanium alloy has significant impact on burr mechanism at both side of groove path. Another point is the difference between the entrance and the exit burr. The exit side burr is bigger than the entrance burr. Aslantas et.al [12] found that a method to reduce the burr generated when machining of titanium alloy was implementing the hybrid cooling lubrication system with combining minimum quantity lubrication and cryogenic system. This method has succeeded in reducing the burr in term of number and size of geometry. Beside of reducing a number of burr and geometry, this method also generated good surface roughness and surface texture. When machining titanium alloys as difficult to cut material, Built-Up-Edge (BUE) raised at the end of cutting edge of tool. This BUE is also affected by the burr formation. BUE can alter the tool geometry by generating the new surface finish including burr formation.

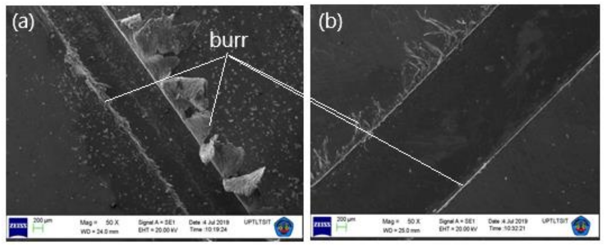

Figure 3: *Burr performance at two sides groove pass under scanning electronic magnetic at spindle speed of 10.000 rpm, depth of cut of 100 µm, feed rate of 0.001 mm/rev: (a) at tool diameter of 1 mm and (b) tool diameter of 2 mm*

Figure 4 shows the burr formation on the both sides of groove path, which have different burr characteristic at each side. At left side of channel or up milling mechanism, a number of burrs produced more than other side. There are small differences of burrs generated between cutting at spindle speed of 15.000 rpm and spindle speed of 10.000 rpm. In general, each side of the groove channel has certain number of burrs. However, machining at spindle speed of 10.000 rpm generated more burrs dominantly at left side or cutting by up milling method. As stated by Kim et.al [6] that the burr formation depended on the workpiece material as well as cutting condition, tool wear and tool geometry. The burr width decreased when the spindle speed increased. Among the cutting parameters, the feed rate is a dominant factor which contributed in the burr formation compare to spindle speed. During machining of titanium, the heat generated is very high so that it caused the titanium deformed plastically. Thus, it generates burr at both sides of groove path [6], [13].

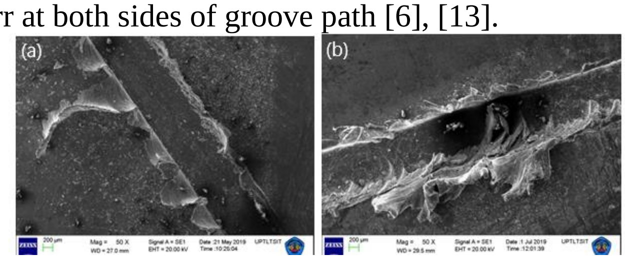

Figure 4: *Burr performance under Scanning electronic magnetic at depth of cut of 150 µm, feed rate of 0.005 mm/rev and tool diameter of 1 mm: (a) at spindle speed of 15.000 rpm (b) spindle speed of 10.000 rpm.*

4. Conclusion

Burr formation during micro end milling material Ti-6Al-4V ELI showed that there were differences burr generated when machining at different cutting parameters and different size of tool diameter. Machining titanium alloy at feed rate of 0.005 mm/rev produced more burr than at feed rate 0.001 mm/rev. The feed rate and depth of cut have significant contribution on the burr formation. Using diameter of cutting tool 2 mm produced smaller number of burr than using tool diameter of 1 mm. Other than that, it also generated shorter burr at both side of the channel. Generally, the burr generated under end micro milling of titanium alloy was different between right side and left side of micro channel. At left side of groove produced, the burr is more than right side. It is possible as effect of cutting mechanism between down and up milling process. The compressive stress pushes the material toward the free surface and generates larger burr.

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References

Anurag, Kumar, R., Roy, S., Joshi, K.K., Sahoo, A.K., and Das, R.K., Machining of Ti-6Al-4V ELI Alloy: A brief review, The 3rd International Conference on Materials and Manufacturing Engineering 2018 IOP Publishing, (2018).

Ibharim, G. A., Arinal, H., Zulhanif and Haron, C,.H. C., Microstructure Alterations of Ti-6Al-4V ELI during Turning by Using Tungsten Carbide Inserts under Dry Cutting Condition, International Journal on Engineering and Technology Development, Vol.1. No.2, pp. 37-40, (2013).

Anurag,Kkumar, R., Joshi, K.K., and Das, R.K., Analysis of Chip Reduction Coefficient in Turning of Ti-6Al-4V ELI, The 3rd International Conference on Materials and Manufacturing Engineering 2018, IOP Publishing, (2018).

Vivek, B., Ajay, K.K., and Ramesh, K.S., Burr Formation and Surface Quality in High Speed Micromilling of Titanium Alloy (Ti6Al4V), ASME Proceedings, Vol.2, (2013).

Tao, Z., Zhanqiang, L., Chonghai X., Influence of size effect on burr formation in micro cutting, International Journal of Advanced Manufacturing Technology, Vol. 68, pp. 1911–1917, (2013).

Kim, D.H., Lee, P.H., and Lee, S.W., Experimental Study on Machinability of Ti-6Al-4V in Micro End-Milling, Proceedings of the World Congress on Engineering 2014 Vol II, London, U.K, (2014).

Bajpai, V., Remesh, K.S., Kushawaha, A.K., Burr formation and surface quality in high speed micromilling of titanium alloy (TI6AI4V), Indian Institute of Technology Bombay, India, (2017).

Lu, Z., Wanqun, C., and Dehong, H., Experimental investigation on burr formation in vibration-assisted micro-milling of Ti-6Al-4V, Journal of Mechanical Engineering Science, pp. 1-8, (2018).

Kunpeng, Z., and Xialong, Y., The monitoring of micro milling tool wear conditions by wear area estimation, Mechanical Systems and Signal Processing, pp. 80–91, (2017).

Uhlamann, E., Oberschmid, Kuche, Lowensten, and Winker, Effects of different cutting edge preparation methods on micro milling performance, TechnischeUniversität Berlin, Pascalstrabe 8-9, 10587 Berlin, Germany, (2016).

Schueler, G.M., Engmann, J., Marx, T., Haberland, R. and Aurich, J.C., Proceeding. CIRP Inter-national Conference, Burrs, Kaiserslautern, Germany, (2010).

Aslantas, K., Alatrusi, L., Bedir, F., Kaynak, Y. And Yilmaz, N. An experimental analysis of minimum chip thickness in micro-milling of two differenct titanium alloys, In Proceedings of the institution of Mechanical Engineering Part B: Journal of Engineering Manufacture, (2020).

Wu, T., Cheng, K. and Rakowski R. Investigation on tooling geometrical effects of micro tools and the associated micro milling performance. Proc IMechE, Part B: J Engineering Manufacture 226(9): 1442–1453, (2012).

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