Single Point Diamond Turning of Tungsten Carbide

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Abstract

The study of single point diamond turning of Tungsten Carbide is presented. The motivation for this study is the material's high hardness and potential application for micromolds. A WC sample was subjected to tests for the determination of cutting parameters to achieve ductile regime of material removal. It was concluded that for lower feedrates, the depth of cut did not influenced the roughness but for larger federates the depth of cut affected significantly the surface finish and life of the tool. The diamond turning of Tungsten Carbide may be a viable option for the production of precision molds.

1 Introduction

Tungsten Carbide (WC) desirable in the industry due to its excellent combination of high strength even at high temperature, fracture strength and corrosion resistance, wear resistance mainly for the fabrication of molds and micromolds [1] [2]. [3]. The machinability of Tungsten Carbide using conventional tools is generally considered poor due to its high hardness which causes premature wear of the cutting edge leading to very poor surface quality. This work is an attempt to use single point diamond turning to produce crack-free surfaces in Tungsten Carbide.

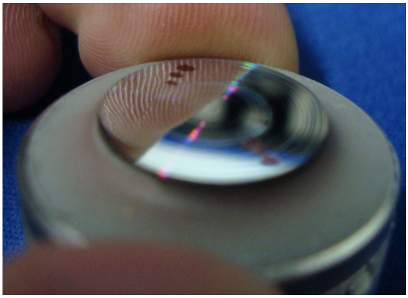
2 Experiments

A 14 mm diameter polycrystalline Tungsten Carbide (WC) sample was used. The material was lapped, polished and then submitted to face turning using different cutting conditions on a Rank Pneumo™ ASG2500 precision lathe. The hardness of the sample was measured with loads varying from 5 to 500 g. The Vickers Hardness was 2600 kgf/mm^2 (load 500gf). Two different diamond tools were used, CO60WG (-25° rake angle) and CO60LG (O° rake angle), both from Contour Fine Tooling™.

Seven regions of the surface were face turned a time for each tool geometry, according to Figure 1(a) (totalizing 14 different cutting conditions). Each region was analyzed using a Veeko™ (Wyko™) NT1100 Profilometer. Fig. 1 (b) shows the machined sample after machining.

	Clearance Angle	*Radius (mm)*	*RPM*	*Rake Angle*	*Depth of cut (nm)*	*Feed Rate (μ m/rev.)*
1	12°	1,52	1000	0°	0,50	1,00
2	12°	1,52	1000	0°	1,00	1,00
3	12°	1,52	1000	0°	2,00	1,00
4	12°	1,52	1000	0°	0,50	3,00
5	12°	1,52	1000	0°	1,00	3,00
6	12°	1,52	1000	0°	2,00	3,00
7	12°	1,52	1000	0°	5,00	1,00
8	12°	1,52	1000	(-25°)	0,50	1,00
9	12°	1,52	1000	(-25°)	1,00	1,00
10	12°	1,52	1000	(-25°)	2,00	1,00
11	12°	1,52	1000	(-25°)	0,50	3,00
12	12°	1,52	1000	(-25°)	1,00	3,00
13	12°	1,52	1000	(-25°)	2,00	2,50
14	12°	1,52	1000	(-25°)	5,00	4,50

a)



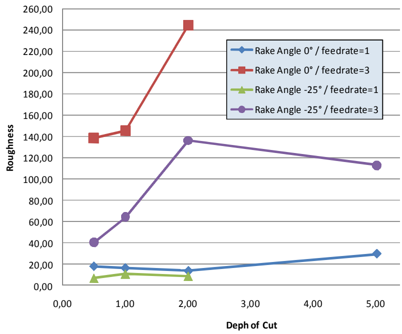
b)

Figure 1: a) Table showing cutting conditions used; and b) WC Sample after machining

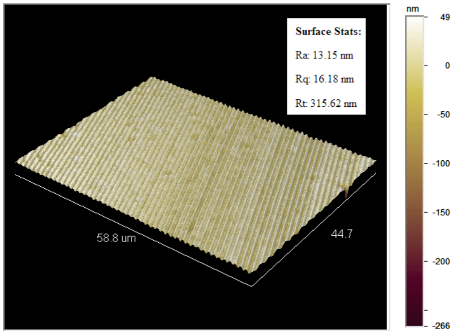
3 Results and Discussions

Figure 2 presents the results of the average surface roughness Ra versus the cutting depth. The results show that the surface roughness increases with the depth of cut. This was attributed to the microcrack formation on the outmost surface. The depth of the cracks were measured for the critical cutting conditions the values are larger than 1 micrometer. For both cutting tools the surface roughness was lower for the smaller federate, however the negative rake angle tool presented the better results. Figure 2 (b) shows a 3D image of the surface machined with the 0^{o} rake angle tool.

Analysis of the cutting edge was using an optical microscope LEICA was carried out. Apparent wear and spalling were not noticed on the cutting edge for parameters smaller or close to 2μm (depth of cut) and 1μm (feedrate). For parameters exceeding these values, damage on the edge of tools was observed. Figure 2 shows the cutting edge of a tool with rake angle 0° after being used in the diamond turning of WC with depth of cut and federate exceeding 2μm and 3μm/revolution, respectively.

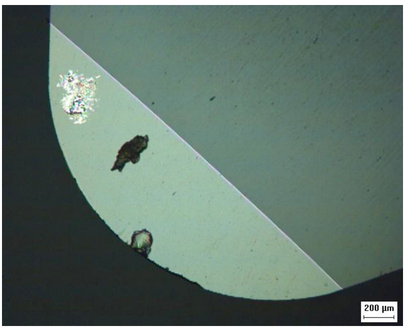


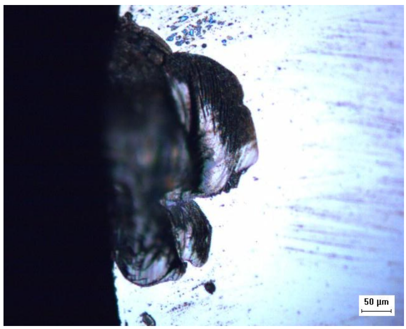
a)



b)

Figure 2. Roughness results (Ra in nanometers) X Deph of Cut (µm) and Feedrate (µm/rev), b) 3D image of the surface machined with -25^{o} rake angle tool f=1 µm/rev.





a) **b)**

Figure 3. a) Cutting edge of tool CO60LG (γ=0°) after the machining process b) detail view of the damage caused to the cutting edge.

4 Conclusions

Based on experimental results, it was concluded that for feedrates of the order of 1 μm/revolution, the depth of cut did not affect significantly the surface roughness and for feedrates of the order of 3 μm/rev, the depth of cut influenced the results greatly. Moreover, chipping of the cutting edge occurred for depths of cut of 2 μm. The diamond machining of tungsten carbide using diamond tools proved to be a viable option for the production of surfaces in terms of optical quality. Thus to obtain a damage free surface in Tungsten Carbide with surface finishes of the order of 10 nm, the cutting depth and feedrate should be smaller than 2 μm and 1 μm/revolution, respectively, using a new diamond tool with rake angle of -25^{o} and a precision high stiffness machine tool.

References:

[1] DELANOE,A.; BACIA, M.; PAUTY, M.; LAY, S.; ALLIBERT, C.H. Cr-Rich Layer at the WC/Co Interface in Cr-Dopped WC-Co Cermets: Segregation or Metastable Carbide? *Journal of Crystal Growth,* September, 2003.

[2] YAMADA,K. Synthesis of Tungsten Carbide by Dynamic Shock Compression of a Tungsten – Acetylene black powder mixture. *Journal of Alloys and Compounds* 2000. p.253-258.

[3] CHENG, X.; WANG, Z.G.; KOBAYASHI, S.; NAKAMOTO, K.; YAMASAKI, K. Tool Fabrication System for Micro/Nano Milling-Function Analysis and Design of a Six Axes Wire EDM/Machine. *International Journal Advanced Manufacturing Technology*. 2010, v.46, p.179-189.

Acknowledgments

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