MACHINING CHARACTERISTICS ANALYSIS OF 6061-T6 ALUMINIUM ALLOY WITH DIAMOND COATED AND UNCOATED TUNGSTEN CARBIDE TOOL

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Abstract*ó *In the present work the examination on machining of 6061-T6 Aluminum compounds utilizing precious stone covered and uncoated tungsten carbide end processes under dry conditions is directed. This composite has extensive variety of uses in the car and numerous different enterprises. For the above investigation, the jewel covering of the apparatuses was performed utilizing CVD process. The execution of the precious stone covered instruments has been contrasted and that of an uncoated apparatus and the outcomes are exhibited and examined in this work.

Keywords - *Aluminium Alloy, Diamond Coated End Mill, Machining Characteristics, Tungsten Carbide Tool, Cutting Force Analysis*

INTRODUCTION

Aluminium and its alloys gained their importance in automobile and aerospace industries due to their high strength to weight ratio. The emerging trend of dry machining has given a real challenge in machining aluminium and its alloys. The chemical affinity of aluminium to different coating materials and its low melting point made this a critical one for machining. Many researches are still going on to find out the best compatible cutting tool for machining aluminium and its alloys. The main problem in machining the aluminium is the formation of built-up edge formation due to the adhesion to the tool materials. The dry machining of aluminium and its alloys produces unacceptable built-up edge on uncoated carbide tool and there is an adverse effect on surface quality of the work piece. This work is aimed at studying the cutting of 6061-T6 aluminium alloy using diamond coated and uncoated tungsten carbide end mills. This material is suitable for machining studies due to its wide range of applications in the aerospace and automotive industries. The machining is conducted on milling machine with 10 mm diameter diamond coated and uncoated end mills. A study of cutting performance of the tools in terms of development of cutting force is carried out at different cutting conditions.

EXPERIMENTAL SETUP

The machining performances of the tools were carried out in milling 6061-T6 aluminium alloy in a CNC milling machine. The tools used are 10 mm diameter uncoated tungsten carbide and diamond coated end mills. The DECKEL AG (Germany) milling machine is used in this experiment (Fig 2). The work piece was held over a 3D piezoelectric dynamometer (Kistler 9257B) for measurement of the cutting forces.(Fx, Fy and Fz). The signals were amplified by charge amplifier (Kistler 5019) and fed to the computer with the help of data acquisition card (Fig. 1), and LabView software was used for the recording of the forces. The machining was carried out for various spindle speed, feed and depth of cut and the variation of cutting forces were recorded.

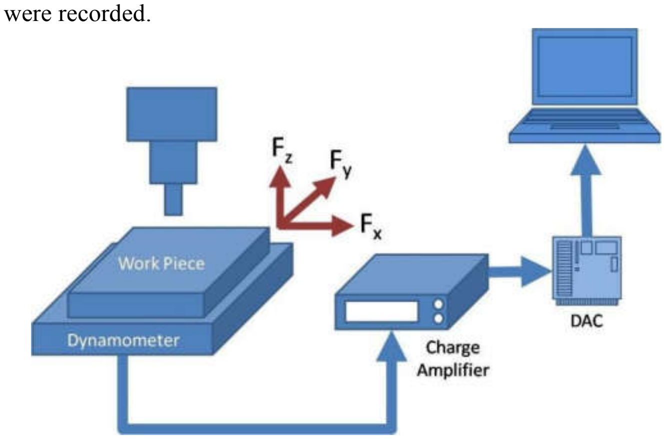

Fig. 1 Schematic of the experimental setup

In this experiment three levels of spindle speed and four levels of feed rate and depth of cuts were used. The tool was moved in the x direction (up milling) giving a constant step over of 4 mm. The cutting parameters were changed manually according to different cutting conditions for each run. The cleaning of the cutting tool after cutting every sample was necessary to avoid built-up edge formation which would affect the surface roughness of the following cut. The tool was also periodically checked to verify the functionality of the cutting edge. All specimens in this experiment were conducted under dry cutting conditions. The cutting forces acting on the tool was studied for these cutting conditions.

TABLE I COMPOSITION OF 6061-T6 ALUMINIUM ALLOY

	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
%	0.4	0.7	0.4	0.15	1.2	0.35	0.25	0.15	96.4

A. *Work Material*

The chemical composition of 6061-T6 aluminium alloy is given in Table I.

Fig 2. Photograph of the experimental setup

B. *Tools used for Machining*

This experiment is conducted by using 10 mm diameter uncoated and diamond coated tungsten carbide end mills with four flutes (Fig.3). The tools were coated with diamond by using Hot Filament Chemical Vapour Deposition (HFCVD) technique.

Fig.3 Diamond coated (top) and uncoated (bottom) Tungsten Carbide Tools

I. EXPERIMENTAL RESULTS

A. *Design of Experimentation*

A factorial design was used in this experiment; for this a combination of cutting parameters based on the work piece and tool materials are selected. Table 2 shows the three levels of spindle speed and four levels of feed rate and depth of cuts used for this experiment.

TABLE II
DESIGN OF EXPERIMENTATION

	Speed (rpm)	Feed (mm/min)	Depth (mm)
Level 1	2000	500	0.5
Level 2	2500	750	0.75
Level 3	3150	1000	1
Level 4		1250	1.25

B. *Experimental Results of Uncoated and Coated Tools*

TABLE III

MACHINING RESULTS OF UNCOATED TOOL

Sl No	Speed (rpm)	Feed (mm/ min)	Depth (mm)	Force Fx (N)	Force Fy (N)	Force Fz (N)
33	3150	500	1	-135.67	-117.37	-8.86
34	3150	750	1	-163.46	-122.72	-12.37
35	3150	1000	1	-192.97	-123.02	-12.9
36	3150	1250	1	-246.67	-156.45	-14.72
37	2000	500	1.25	-273.12	-199.25	-20.12
38	2000	750	1.25	-316.24	-221.15	-21.29
39	2000	1000	1.25	-372.39	-243.05	-22.46
40	2000	1250	1.25	-397.45	-264.95	-23.63
41	2500	500	1.25	-345.65	-177.02	-19.02
42	2500	750	1.25	-365.46	-198.93	-20.18
43	2500	1000	1.25	-384.93	-220.81	-21.35
44	2500	1250	1.25	-406.75	-242.73	-22.52
45	3150	500	1.25	-152.34	-148.07	-17.56
46	3150	750	1.25	-182.46	-171.43	-18.73
47	3150	1000	1.25	-203.67	-191.88	-19.91
48	3150	1250	1.25	-268.19	-214.42	-21.06

In this Fx, Fy and Fz are the maximum forces in the respective directions.

TABLE IV Machining Results of Coated tool chining

Sl No	Speed (rpm)	Feed (mm/ min)	Depth (mm)	Force Fx (N)	Force Fy (N)	Force Fz (N)
1	2000	500	0.5	-18.01	-42.82	-5.88
2	2000	750	0.5	-21.23	-54.45	-6.53
3	2000	1000	0.5	-25.89	-64.19	-7.5
4	2000	1250	0.5	-29.45	-83.85	-12.13
5	2500	500	0.5	-15.12	-34.97	-0.91
6	2500	750	0.5	-18.26	-36.9	-3.29
7	2500	1000	0.5	-23.68	-53.1	-5.58
8	2500	1250	0.5	-28.45	-66.3	-8.89
9	3150	500	0.5	-16.12	-27.31	-4.64
10	3150	750	0.5	-19.12	-31.38	-1.02
11	3150	1000	0.5	-24.75	-44.08	-2.16
12	3150	1250	0.5	-29.46	-53.27	-4.68
13	2000	500	0.75	-20.12	-61.22	-10.36
14	2000	750	0.75	-24.46	-75.93	-13.16
15	2000	1000	0.75	-28.54	-90.63	-15.96
16	2000	1250	0.75	-30.34	-105.33	-18.76

Results of Coated tool

Sl No	Speed (rpm)	Feed (mm/m in)	Depth (mm)	Force Fx (N)	Force Fy (N)	Force Fz (N)
1	2000	500	0.5	-150.45	-97.53	-0.59
2	2000	750	0.5	-161.34	-103.45	-1.92
3	2000	1000	0.5	-167.45	-114.59	-3.45
4	2000	1250	0.5	-189.23	-142.21	-4.44
5	2500	500	0.5	-287.32	-54.46	-0.21
6	2500	750	0.5	-301.73	-66.15	-1.23
7	2500	1000	0.5	-329.05	-76.97	-1.66
8	2500	1250	0.5	-357.1	-109.95	-3.43
9	3150	500	0.5	-241.81	-45.38	-0.12
10	3150	750	0.5	-259.38	-59.18	-0.45
11	3150	1000	0.5	-274.01	-69.44	-0.85
12	3150	1250	0.5	-298.88	-89.03	-1.57
13	2000	500	0.75	-251.01	-110.75	-7.42
14	2000	750	0.75	-271.65	-132.65	-8.59
15	2000	1000	0.75	-295.12	-154.55	-9.76
16	2000	1250	0.75	-331.23	-176.45	-10.93
17	2500	500	0.75	-232.36	-88.5	-6.31
18	2500	750	0.75	-257.23	-110.4	-7.43
19	2500	1000	0.75	-271.18	-132.3	-8.65
20	2500	1250	0.75	-290.92	-154.21	-9.84
21	3150	500	0.75	-210.43	-59.58	-4.86
22	3150	750	0.75	-231.46	-81.48	-6.03
23	3150	1000	0.75	-250.91	-104.24	-7.19
24	3150	1250	0.75	-272.58	-126.31	-8.36
25	2000	500	1	-262.99	-167.38	-14.43
26	2000	750	1	-304.57	-181.39	-14.94
27	2000	1000	1	-361.13	-238.99	-18.38
28	2000	1250	1	-382.12	-258.83	-17.28
29	2500	500	1	-337.88	-112.38	-11.98
30	2500	750	1	-354.41	-121.79	-13.83
31	2500	1000	1	-378.03	-133.43	-16.05
32	2500	1250	1	-392.45	-172.45	-16.16

In this Fx, Fy and Fz are the maximum forces in the respective directions.

C. Analysis of Results

The following graphs show the variation of Forces with respect to feed and depth at constant speed (2000 rpm)

1) Feed Vs Force Fx ñ a comparative study

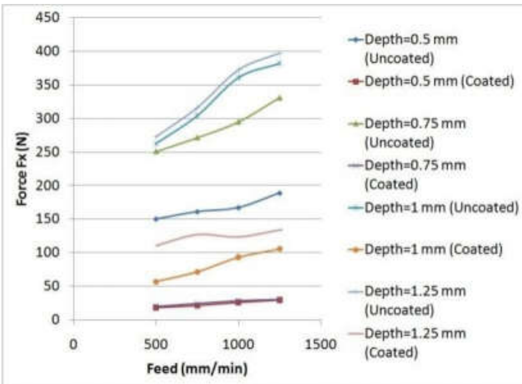

Fig. 4, Variation of Force Fx Vs Feed for Uncoated and Coated tools

2) Depth Vs Force Fx ñ a comparative study

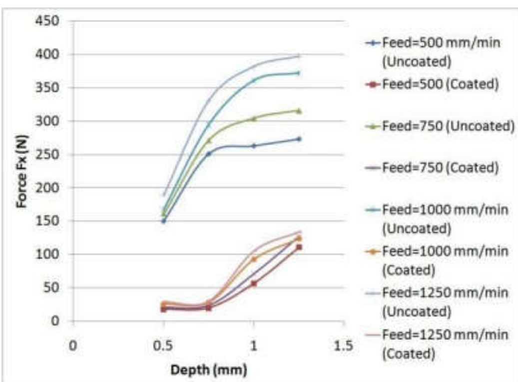

Fig. 5, Variation of Force Fx Vs Depth for Uncoated and Coated tools

The forces are observed to be increasing with depth and feed for both coated and uncoated tools. The cutting forces experienced on the diamond tool are found to be far less than the uncoated tools (Fig. 4, Fig. 5). This is attributed to high thermal conductivity of diamond coated tool which prevents the sticking of work material to the rake surface of the end mill which reduces the cutting forces. The lesser cutting force is also attributed by the tribological property of the diamond which generally reduces the friction. The surface roughness values obtained with diamond coated tool is found to be almost constant for different feed and depth of cuts; whereas the uncoated tool gave wide variation in the surface roughness. The low affinity of diamond to the workpiece prevents the formation of built-up edge which improves the surface finish of the workpiece.

Sl No	Speed (rpm)	Feed (mm/ min)	Depth (mm)	Force Fx (N)	Force Fy (N)	Force Fz (N)
17	2500	500	0.75	-17.14	-43.68	-7.11
18	2500	750	0.75	-19.82	-58.38	-9.92
19	2500	1000	0.75	-25.14	-73.08	-12.72
20	2500	1250	0.75	-29.89	-87.78	-15.52
21	3150	500	0.75	-16.87	-25.86	-2.9
22	3150	750	0.75	-19.77	-35.56	-5.71
23	3150	1000	0.75	-22.34	-50.26	-8.53
24	3150	1250	0.75	-31.17	-64.96	-11.36
25	2000	500	1	-56.86	-74.37	-15.76
26	2000	750	1	-71.47	-97.4	-19.78
27	2000	1000	1	-93.18	-117.05	-23.52
28	2000	1250	1	-105.67	-126.8	-25.38
29	2500	500	1	-50.08	-58.93	-15.22
30	2500	750	1	-67.83	-79.85	-16.54
31	2500	1000	1	-80.86	-88.32	-20.57
32	2500	1250	1	-91.11	-109.25	-22.14
33	3150	500	1	-44.73	-49.53	-7.63
34	3150	750	1	-57.34	-57.04	-12.33
35	3150	1000	1	-76.32	-74.34	-16.58
36	3150	1250	1	-88.69	-86.44	-17.93
37	2000	500	1.25	-110.9	-104.18	-23.61
38	2000	750	1.25	-127.41	-118.88	-26.41
39	2000	1000	1.25	-123.93	-133.58	-29.24
40	2000	1250	1.25	-134.4	-148.28	-32.05
41	2500	500	1.25	-94.7	-86.63	-20.37
42	2500	750	1.25	-108.34	-101.33	-23.17
43	2500	1000	1.25	-114.43	-116.03	-25.97
44	2500	1250	1.25	-123.32	-130.73	-28.76
45	3150	500	1.25	-73.64	-63.81	-16.15
46	3150	750	1.25	-82.35	-78.51	-18.95
47	3150	1000	1.25	-90.38	-93.21	-21.75
48	3150	1250	1.25	-102.14	-107.91	-24.55

CONCLUSIONS

The work piece materials used in the experiment were specified as aluminum 6061-T6 alloy. To make this system available to be applied more extensively and develop an overall model, different work piece materials which are widely used in the industry such as carbon steel, aluminum alloys 380 and 390, alloy steel and steel SAE 1018 could be investigated. The study would also be extended using micro end mills after coating the same with diamond and other hard layers of CVD coating. In addition proper combination of multi layer hard coating could be tried out to understand the performance improvement.

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REFERENCES

1. X.M. Meng, W.Z. Tang, L.F. Hei, C.M. Li, S.J. Askari, G.C. Chen, F.X. Lu (2008). Application of CVD nanocrystalline diamond films to

cemented carbide drills. *International Journal of Refractory Metals & Hard Materials 26 (2008) 485ñ490*

2. Y.P. Ma, F.H. Sun, H.G. Xue, Z.M. Zhang, M. Chen (2007) Deposition and characterization of nanocrystalline diamond films on Co-cemented tungsten carbide inserts, *Diamond & Related Materials 16 481ñ485*
3. Patrick J. Heaney, Anirudha V. Sumant, Christopher D. Torres, Robert W. Carpick, Frank E. Pfefferkorn (2008) Diamond coatings for micro end mills: Enabling the dry machining of aluminum at the micro-scale, *Diamond & Related Materials 17 223ñ233*
4. P. Roy, S.K. Sarangi, A. Ghosh, A.K. Chattopadhyay (2009) Machinability study of pure aluminium and Alñ12% Si alloys against uncoated and coated carbide inserts. *Int. Journal of Refractory Metals & Hard Materials 27 535ñ544*
5. Tug¢rul Ozel, Yigit Karpat (2005) Predictive modeling of surface roughness and tool wear in hard turning using regression and neural networks, *International Journal of Machine Tools & Manufacture 45 467ñ479*
6. Yu-Hsuan Tsai, Joseph C. Chen, Shi-Jer Lou (1999) An in-process surface recognition system based on neural networks in end milling cutting operations. *International Journal of Machine Tools & Manufacture 39 583ñ605*
7. Kurapati Venkatesh, Mengchu Zhou, Reggie J Caudill, (1997) Design of artificial neural networks for tool wear monitoring, *Journal of Intelligent Manufacturing 8, 215-226..*
8. K.A. Abou-El-Hossein, K. Kadirgama, M. Hamdi, K. Y. Benyounis (2007), Prediction of cutting force in end-milling operation of modified AISI P20 tool steel, *Journal of Materials Processing Technology 182 241ñ247*
9. Muammer Nalbant, HasanGokkaya, Ihsan Toktas, Gokhan Sur (2009), The experimental investigation of the effects of uncoated, PVD- and CVD-coated cemented carbide inserts and cutting parameters on surface roughness in CNC turning and its prediction using artificial neural networks, *Robotics and Computer-Integrated Manufacturing 25 211ñ223*
10. P.G. Benardos, G.C. Vosniakos (2002), Prediction of surface roughness in CNC face milling using neural networks and Taguchiís design of experiments, *Robotics and Computer Integrated Manufacturing 18 343ñ354*
11. H. Hanyu, S. Kamiya, Y. Murakami, M. Saka (2003). Dry and semi-dry machining using finely crystallized diamond coating cutting tools, *Surface and Coatings Technology 173 ñ174 992ñ995*
12. G. List, M. Nouari, D. Gehin, S. Gomez, J.P. Manaud, Y. Le Petitcorps, F. Girot (2005). Wear behaviour of cemented carbide tools in dry machining of aluminium alloy, *Wear 259 1177ñ1189*
13. V.D. Calatoru, M. Balazinski, J.R.R. Mayer, H. Paris, G. LíEsperance (2008), Diffusion wear mechanism during high-speed machining of 7475-T7351 aluminum alloy with carbide end mills, *Wear 265 1793ñ 1800*
14. Balkrishna Rao, Yung C. Shin (2001), Analysis on high-speed face- milling of 7075-T6 aluminum using carbide and diamond cutters, International Journal of Machine Tools & Manufacture 41 1763ñ178