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Surface Finish Characteristics Analysis of Machining 6061-T6 Aluminium Alloy with Diamond Coated and Uncoated Tungsten Carbide Tool

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***Abstract* - In the present work the study on machining of 6061-T6 Aluminium alloys using diamond coated and uncoated tungsten carbide end mill under dry conditions is conducted. This alloy has wide range of applications in automotive and many other industries. For the study, the diamond coating of the tools was performed using CVD process. The surface finish characteristics has been presented and analyzed in this work.**

Keywords - ***Aluminium Alloy, Diamond Coated End Mill, Machining Characteristics, Tungsten Carbide Tool, Surface Finish***

I. INTRODUCTION

Aluminium and its alloys find wide range of applications in aerospace and automotive industries due to their high strength to weight ratio and hence their machining characteristics are of great importance. The emerging trend of dry machining has given a real challenge to machining these materials.. The low melting point and chemical affinity of aluminium based alloys to different coating materials are critical to effective 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 aluminium is the built-up edge formation due to the adhesion of chips to the cutting tool. 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. The present work is aimed at studying the cutting characteristics of 6061-T6 aluminium alloy using diamond coated and uncoated tungsten carbide end mills. The machining is conducted on milling machine with 10 mm diameter diamond coated and uncoated end mills. Surface finish of the work piece at different cutting conditions is measured and analysed in this work.

II. 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 1). The machining was carried out for various spindle speed, feed and depth of cut and the variation of surface finish were recorded.

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.

COMPOSITION OF 6061-T6 ALUMINIUM ALLOY

TABLE I

	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 1. 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.2). The tools were coated with diamond by using Hot Filament Chemical Vapour Deposition (HFCVD) technique.

Fig.2 Diamond coated (top) and uncoated (bottom) Tungsten Carbide Tools

III. 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)	Ra (μm)
1	2000	500	0.5	0.97
2	2000	750	0.5	2.41
3	2000	1000	0.5	2.86
4	2000	1250	0.5	3.72
5	2500	500	0.5	0.78
6	2500	750	0.5	1.49
7	2500	1000	0.5	2.2
8	2500	1250	0.5	2.85
9	3150	500	0.5	0.63
10	3150	750	0.5	0.73
11	3150	1000	0.5	1.34
12	3150	1250	0.5	1.84
13	2000	500	0.75	1.57
14	2000	750	0.75	2.54
15	2000	1000	0.75	3.12
16	2000	1250	0.75	3.76
17	2500	500	0.75	1.52
18	2500	750	0.75	1.61
19	2500	1000	0.75	2.72
20	2500	1250	0.75	3.14
21	3150	500	0.75	0.61
22	3150	750	0.75	0.72
23	3150	1000	0.75	1.21
24	3150	1250	0.75	2.23
25	2000	500	1	2.07
26	2000	750	1	2.64
27	2000	1000	1	2.84
28	2000	1250	1	3.91
29	2500	500	1	0.79
30	2500	750	1	1.63
31	2500	1000	1	2.96
32	2500	1250	1	3.34
33	3150	500	1	0.67
34	3150	750	1	0.86
35	3150	1000	1	1.37
36	3150	1250	1	2.34
37	2000	500	1.25	2.21
38	2000	750	1.25	2.61
39	2000	1000	1.25	3.16
40	2000	1250	1.25	3.97
41	2500	500	1.25	1.16
42	2500	750	1.25	2.76
43	2500	1000	1.25	3.31
44	2500	1250	1.25	3.83
45	3150	500	1.25	1.31
46	3150	750	1.25	1.81
47	3150	1000	1.25	2.45
48	3150	1250	1.25	3.06

TABLE IV

MACHINING RESULTS OF COATED TOOL

Sl No	Speed (rpm)	Feed (mm/min)	Depth (mm)	Ra (µm)
1	2000	500	0.5	1.33
2	2000	750	0.5	1.39
3	2000	1000	0.5	1.47
4	2000	1250	0.5	1.53
5	2500	500	0.5	1.48
6	2500	750	0.5	1.47
7	2500	1000	0.5	1.51
8	2500	1250	0.5	1.56
9	3150	500	0.5	1.35
10	3150	750	0.5	1.45
11	3150	1000	0.5	1.51
12	3150	1250	0.5	1.57
13	2000	500	0.75	1.42
14	2000	750	0.75	1.46
15	2000	1000	0.75	1.51
16	2000	1250	0.75	1.58
17	2500	500	0.75	1.49
18	2500	750	0.75	1.52
19	2500	1000	0.75	1.57
20	2500	1250	0.75	1.59
21	3150	500	0.75	1.42
22	3150	750	0.75	1.48
23	3150	1000	0.75	1.54
24	3150	1250	0.75	1.62
25	2000	500	1	1.42
26	2000	750	1	1.47
27	2000	1000	1	1.48
28	2000	1250	1	1.61
29	2500	500	1	1.35
30	2500	750	1	1.53
31	2500	1000	1	1.58
32	2500	1250	1	1.65
33	3150	500	1	1.45
34	3150	750	1	1.52
35	3150	1000	1	1.54
36	3150	1250	1	1.66
37	2000	500	1.25	1.43
38	2000	750	1.25	1.49
39	2000	1000	1.25	1.53
40	2000	1250	1.25	1.64
41	2500	500	1.25	1.39
42	2500	750	1.25	1.54
43	2500	1000	1.25	1.59
44	2500	1250	1.25	1.69
45	3150	500	1.25	1.48
46	3150	750	1.25	1.53
47	3150	1000	1.25	1.58
48	3150	1250	1.25	1.64

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 Ra – a comparative study*

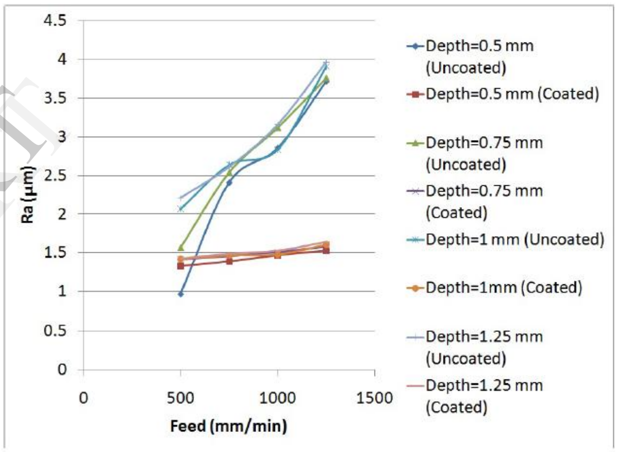

Fig. 3, Variation of Feed Vs Ra for Uncoated and Coated tools

2) *Depth Vs Ra – a comparative study*

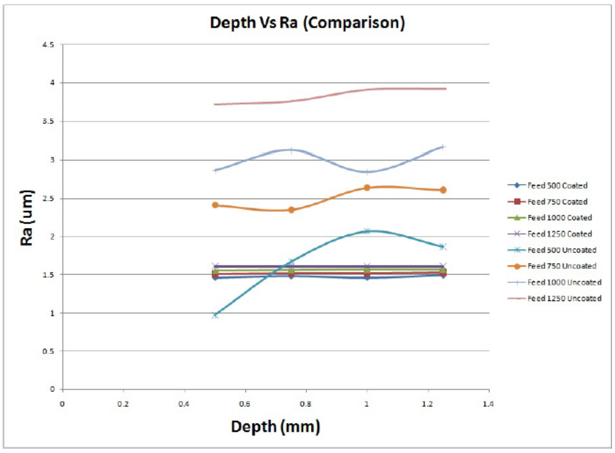

Fig. 4, Variation of Force FxVs Depth for Uncoated and Coated tools

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 values (Fig 3, Fig 4). For lower feed rates the surface roughness obtained with coated and uncoated tools were almost the same. But at higher feeds the surface quality is far less than the coated tool. The low affinity of diamond to the workpiece prevents the formation of built-up edge which increases the surface finish of the workpiece.

IV. CONCLUSIONS

It is observed that the variation of feed rate from 500 mm/min to 1250 mm/min sharply increases surface roughness values ie. over a range of 1.5µm to 4.5 µm for uncoated tools while these values remain more or less constant at a value of 1.5 µm irrespective of feed rate, pointing to the effectiveness of coated tools in getting good surface finish even at high feed rate. With uncoated tools the increase in depth of cut increases the surface roughness while with coated tools the surface roughness is more or less independent of the depth of cut. The above conclusions point to the fact that, with the use of diamond coated tools we can improve the feed rate and depth of cut in machining 6061-T6 aluminium alloy.

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