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A Parametric Study on Performance of Titanium Alloy Using Coated and Uncoated Carbide Insert in CNC Turning

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Abstract

This study considers a comparison of surface roughness obtained by coated carbide inserts and uncoated carbide inserts during dry turning of titanium alloy. Titanium alloy has many applications such as engine valves, connecting rod, suspension springs, airframe components, etc. due to their properties such as high strength to weight ratio, heat treatable and better corrosion resistance. In this experimental work turning on titanium alloy with different cutting parameters like cutting speed, feed and depth of cut has been carried out. Experimentation was carried out using Taguchi's L_9 orthogonal array. Surface roughness was measured for each experimentation. Parameters were optimised and analysis of variance (ANOVA) was carried out. The assessment gives that, when compared to uncoated carbide inserts, the coated carbide inserts shows significantly improved surface roughness.

Keywords: ANOVA, Coated and uncoated carbide inserts, Taguchi's Method, Titanium alloy.

INTRODUCTION:

Lightweight materials such as titanium alloys are now used in modern aerospace structure due to their best combination of metallurgical and physical properties. Titanium's advantages are high strength-to-weight ratio, low density, excellent corrosion resistance, excellent erosion resistance and low modulus of elasticity. However, titanium and its alloy have poor machinability; this may be due to their high chemical reactivity with most cutting tools and therefore, have a tendency to weld to the cutting tool during machining.

Nowadays, most of the carbide cutting tools are coated with CVD or PVD hard coatings. PVD–TiAlN-coated carbide tools are used frequently in metal cutting process due to their high hardness, wear resistance and chemical stability; they offer benefits in terms of tool life and machining performance.

EXPERIMENTAL CONDITIONS AND PROCEDURES:

Experiments were carried out to study tool wear and surface roughness with respect to different experimental conditions for coated and uncoated inserts in hard turning of Titanium (Ti6Al4V) alloy (Approx. 334 BHN) in dry environment. The experimental conditions are selected by using Taguchi's L9 Orthogonal array.

Test Specimen:

The material used in the hard turning was Titanium (Ti6Al4V) alloy of 100 mm length 30 mm diameter. Chemical composition of the material is as shown in table 1. The hardness of workpiece material is approximately 334 BHN.

Table 1: Chemical makeup % of Titanium alloy

Name	Al	V	Fe	O	C	Cu	N	Ti
Percentage	6%	4%	0.4%	0.2%	0.08%	0.3%	0.05%	Bal.

Machine Tool:

Machining experiments has been performed on CNC Lathe equipped with variable spindle speed from 140 – 3350 rpm and 15 KW of connected load. Experiments are carried out under dry environmental condition.

Cutting Inserts:

In tests commercially available coated and uncoated inserts (manufactured by ISCAR) of ISO designation CNMG 120408 (80^0 diamond shaped insert) have been used for experimentation. These inserts are mounted on Sandwick tool holder designated by ISO as PCLNR2525 M12.

Cutting Conditions:

Cutting conditions are selected using Taguchi based design of experiments. Three levels and three parameters are selected for experimentation. These levels and parameters are as shown in Table [2].

Table 2: Machining Parameters and their levels

Variables	Unit	Level 1	Level 2	Level 3
Speed	m/min.	80	100	120
Feed	mm/rev.	0.05	0.10	0.15
Depth of Cut	Mm	0.5	1.0	1.5

Surface Roughness Measurement:
The arithmetic average surface roughness (Ra) of the workpiece is measured by using Surface Roughness Tester as shown in figure. The cut off length and assessment length was fixed as 0.8 mm and 5 mm respectively. The instrument was calibrated using a standard calibration block prior to the measurements. The measurement was taken at four locations (90° apart) around the circumference of the workpiece.

Total Material Removed:
The total material removal is obtained by using the formula,

$$\text{Total material removal rate} = \frac{\pi}{4} \text{ x } [(D_1)^2 - (D_2)^2] \text{ x L x } \varrho$$

Where, D_1 = initial diameter of the rod in mm, D_2 = final diameter of the rod in mm, L = length of material to be cut in mm, ϱ = density of material in g/cc.

RESULTS AND DISCUSSIONS:
The experiments are carried out using orthogonal array. The variation of surface roughness with coated carbide inserts and uncoated carbide inserts are shown in table [4].

Table 4: Experimental Results

Sr. No.	Control Factors			Coated Tool	Uncoated Tool
	Speed (m/min.)	Feed (mm/rev)	Depth of Cut (mm)	Surface Roughness (μm Ra)	Surface Roughness (μm Ra)
1	80	0.05	0.5	0.359	0.470
2	80	0.10	1.0	0.541	0.586
3	80	0.15	1.5	0.988	1.182
4	100	0.05	1.0	0.378	0.492
5	100	0.10	1.5	0.874	0.982
6	100	0.15	0.5	0.564	0.703
7	120	0.05	1.5	0.526	0.546
8	120	0.10	0.5	0.443	0.680
9	120	0.15	1.0	0.696	0.935

Analysis of Variance (ANOVA):
The experimental results from table were analysed with analysis of variance (ANOVA), which used for identifying the factors significantly affecting the performance measures. The results of the ANOVA with the surface roughness are shown in tables. This analysis was carried out for confidence level of 80 %. The sources with a P-value less than 0.2 are considered to have high percentage of contribution to the performance measures. The last column of the tables shows the percent contribution of significant source of the total variation and indicating the degree of influence on the result.

ANOVA for surface roughness using coated insert is shown in Table 5. It is observed from the ANOVA table, the depth of cut (50.22%) is the most significant cutting parameter followed by feed (43.51%). However, speed has least effect (02.31%) in controlling the surface roughness which is not statistically significant.

Table 5: ANOVA for Surface Roughness of Coated Carbide Insert

Source	DF	Seq. SS	Adj. MS	F	P	Percentage Contribution
Speed (m/min.)	2	0.008635	0.004317	0.58	0.634	2.31
Feed (mm/rev.)	2	0.164039	0.082019	10.95	0.084	43.51
DOC (mm)	2	0.189335	0.094667	12.63	0.073	50.22
Error	2	0.014988	0.007494			3.96
Total	8	0.376996				
S = 0.0865666 R-Sq. = 96.02% R-Sq.(adj.) = 84.10%						

Table 6 shows the results of ANOVA for Surface Roughness using uncoated tool. It is observed from the ANOVA table, the feed (57.22%) is the most significant cutting parameter followed by depth of cut (27.53%). However, speed has least effect (2.24%) in controlling the surface roughness which is not statistically significant.

Table 6: ANOVA for Surface Roughness of Uncoated Carbide Insert

Sources	DF	Seq. SS	Adj. MS	F	P	Percentage Contribution
Speed (m/min.)	2	0.01100	0.00550	0.16	0.928	01.24
Feed (mm/rev.)	2	0.28146	0.14073	4.46	0.184	57.92
DOC (mm)	2	0.13543	0.16771	2.11	0.318	27.83
Error	2	0.06391	0.03195			12.99
Total	8	0.49189				
S = 0.178754 R-Sq. = 87.01% R-Sq.(adj.) = 48.03%						

Main effect plots:

The plots show the variation of individual response with the three parameters; cutting speed, depth of cut and feed separately. In the plots, the x-axis indicates the value of each process parameters at three level and y-axis the response value. The main effect plots are used to determine the optimal design conditions to obtain the low surface roughness. The main effect plot for surface roughness for coated carbide insert is shown in Figure 1. The results show that with the increase in cutting speed there is a continuous decrease in surface roughness. On the other hand, as the feed increases the surface roughness increases. However, with the increase in depth of cut there is an increase in surface roughness. Based on analysis using Figure 1 low value of surface roughness was obtained at cutting speed of 120 m/min, Feed of 0.05 mm/rev and DOC of 0.5mm.

The main effect plot for surface roughness for uncoated carbide tool insert is shown in Figure 2. The results show that with the increase in cutting speed there is a continuous decrease in surface roughness. On the other hand, as the feed increases the surface roughness increases. However, with the increase in depth of cut there is an increase in surface roughness. Low value of surface roughness was obtained at cutting speed of 120 m/min, Feed of 0.05 mm/rev and DOC of 0.5 mm.

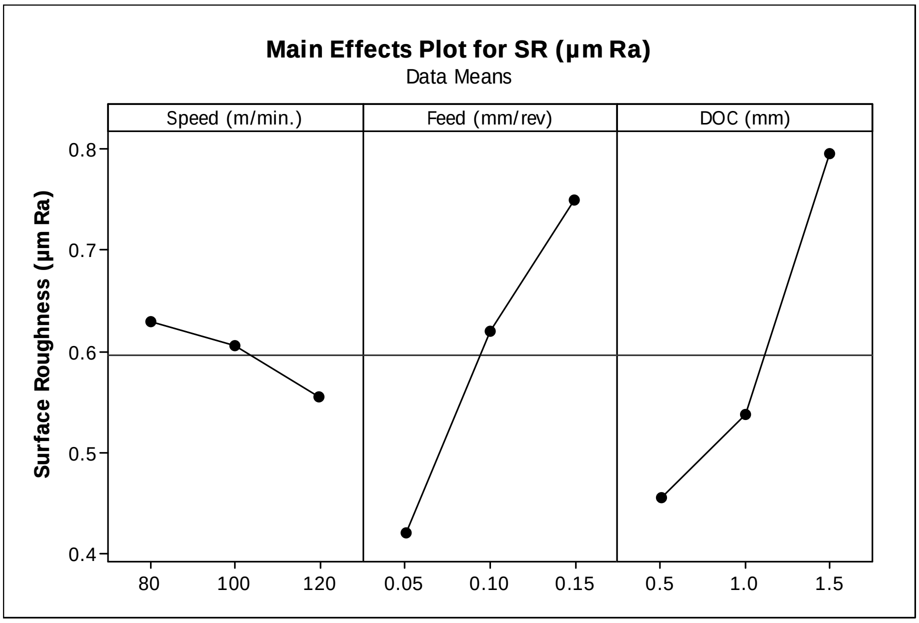

Figure 1: Main effect plot for surface roughness using coated carbide insert.

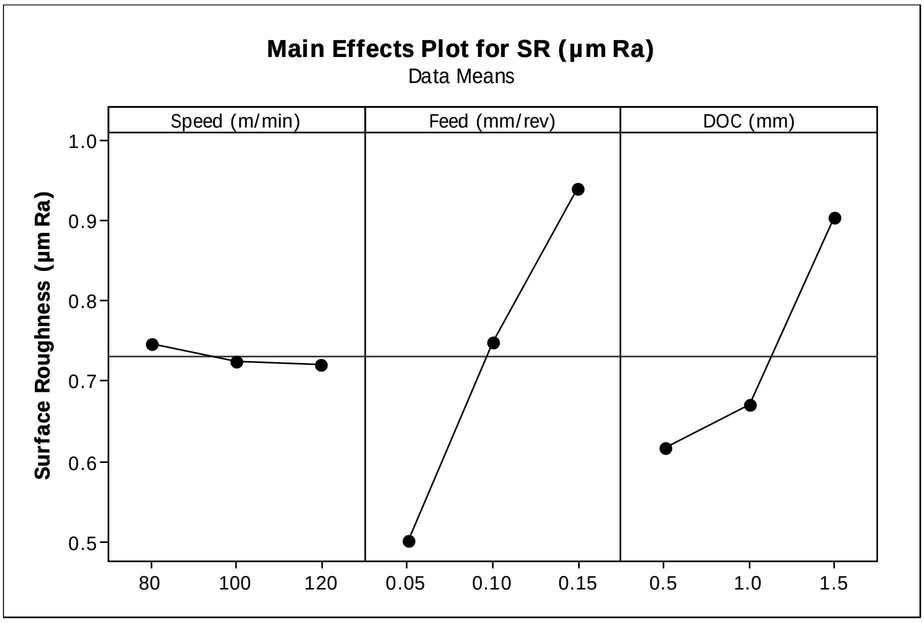

Figure 2: Main effect plot for surface roughness using uncoated carbide insert.

COMPARATIVE STUDY:

From experimental results obtained, the graphs are plotted as shown below. These graphs are plotted at constant speed with varying feed and depth of cut

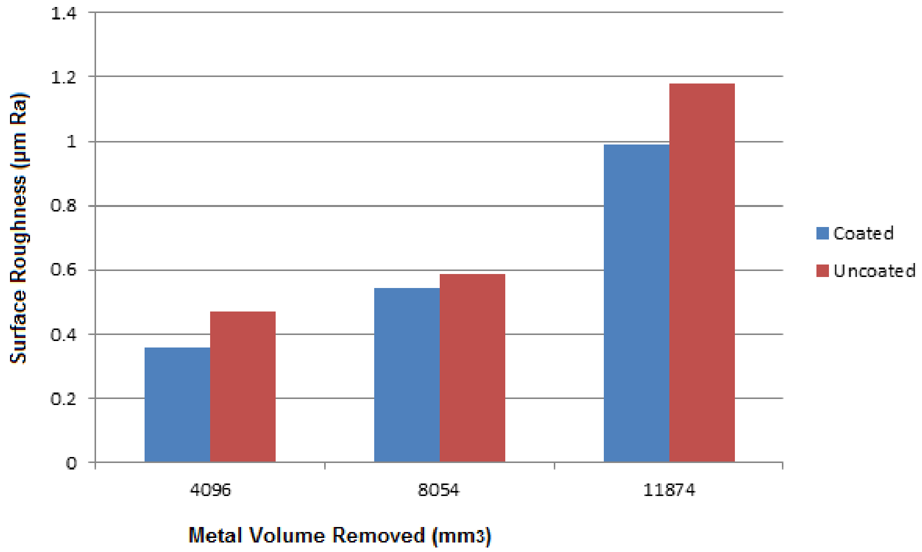

Figure 3: Comparision of Surface Roughness at constant speed of 80 m/min. with varying feed as 0.05 mm/rev., 0.10 mm/rev., 0.15 mm/rev. and depth of cut as 0.5mm, 1.0mm, 1.5mm

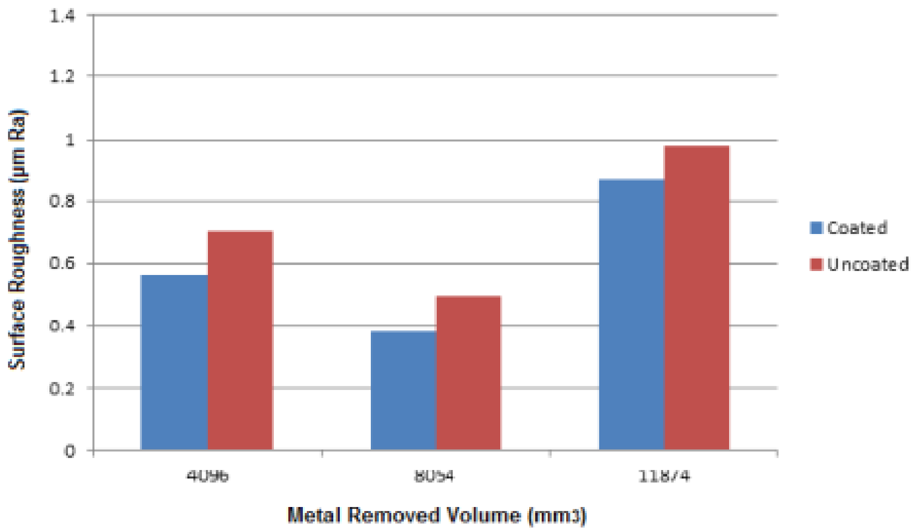

Figure 4: Comparision of Surface Roughness at constant speed of 100 m/min. with varying feed as 0.15 mm/rev., 0.05 mm/rev., 0.10 mm/rev. and depth of cut as 0.5mm, 1.0mm, 1.5mm.

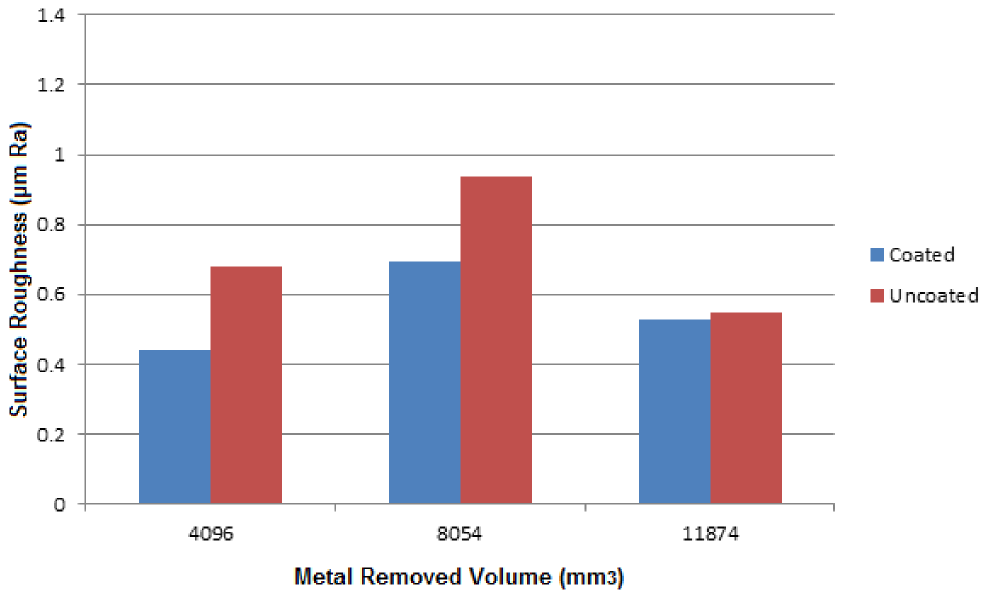

Figure 5: Comparision of Surface Roughness at constant speed of 120 m/min. with varying feed as 0.10m/rev., 0.15 m/rev., 0.05 m/rev. and depth of cut as 0.5mm, 1.0mm, 1.5mm

From the graphs obtained it is clear that the surface roughness obtained from coated carbide inserts are less than that of the surface roughness obtained uncoated carbide inserts.

CONCLUSION:

In this paper a study for the surface roughness concerning the hard turning of Ti-6Al-4V alloy is carried out using coated and uncoated carbide inserts. From the experimental results it is observed that,

1. The coated carbide inserts shows better performance compared with uncoated carbide inserts in terms of surface roughness of workpiece.
2. From ANOVA of coated carbide inserts for surface roughness it is observed that depth of cut (50.22 %) is the most significant factor.
3. From ANOVA of uncoated carbide inserts for surface roughness it is observed that feed (57.92 %) is the most significant factor.
4. It is observed that, with the increase in depth of cut there is increase in the surface roughness for both inserts.
5. It is observed that, with the increase in speed there is decrease in the surface roughness for both inserts.
6. It is observed that, with the increase in feed there is increase in the surface roughness for both inserts.

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