AN EXPERIMENTAL STUDY ON PERFORMANCE OF TITANIUM ALLOY USING COATED AND UNCOATED INSERTS IN CNC TURNING

[1]Digvijay K. Patil, [2]Kaveri N. Kudave, [3]Pooja A. Sutar
[1] Assistant professor, [2]Student, [3]Student
[1] Department of Mechanical Engineering,
[1]Padmbhushan Vasantraodada Patil Institute of Technology, Budhgaon, Maharashtra, India

Abstract— This study considers a comparison of surface roughness and tool wear 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 and tool wear was measured for each experimentation. Parameters were analysed by analysis of variance (ANOVA). The assessment gives that, when compared to uncoated carbide inserts, the coated carbide inserts shows significantly improved surface roughness.

Keywords: ANOVA, Coated and uncoated Inserts, Taguchi's Method, Titanium Alloy.

1. 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.

2. 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.

2.1 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:

The hardness of workpiece material is approximately 334 BHN. Cutting has been carried out on 20 mm length.

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.

2.2 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.

2.3 Cutting Inserts

In tests commercially available uncoated and coated 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.

2.4 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

2.5 Material Removed

Material Removed in any machining process affects the productivity. In order to increase productivity, MRR should be monitored and is given as below

Total material removed = $\frac{\pi}{4}$ x $[(D_1)^2 - (D_2)^2]$ x L x ρ

Where, D1 = 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

2.6 Surface Roughness Measurement

The arithmetic average surface roughness (Ra) of the workpiece is measured by using Surface Roughness Tester. 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.

2.7 Tool Maker's Microscope

Tool flank wear (V_B) is measured by using tool maker's microscope of 0.005 mm accuracy after properly placing the tool below the lens of the microscope to get good view of the tool flank surface. Accurate measurements are carried out by proper focusing and by providing proper illumination of the tool flank surface. After each test the cutting tool was measured with the optical tool microscope to determine the degree of flank wear

3. RESULTS AND DISCUSSION

Table 3: Experimental Results

Sr. No.	Control Factors			Coated Carbide Tool		Uncoated Carbide Tool	
	Speed (rpm)	*Feed (mm/rev)*	*Depth of Cut (mm)*	*Surface Roughness (µm Ra)*	*Tool Wear (mm)*	*Surface Roughness (µm Ra)*	*Tool Wear (mm)*
1	80	0.05	0.5	0.320	0.055	0.470	0.065
2	80	0.10	1.0	0.541	0.065	0.586	0.075
3	80	0.15	1.5	0.925	0.090	1.182	0.105
4	100	0.05	1.0	0.372	0.070	0.492	0.075
5	100	0.10	1.5	0.851	0.115	0.982	0.135
6	100	0.15	0.5	0.534	0.075	0.703	0.080
7	120	0.05	1.5	0.525	0.140	0.546	0.155
8	120	0.10	0.5	0.443	0.075	0.680	0.080
9	120	0.15	1.0	0.726	0.090	0.935	0.100

3.1 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 and tool wear are shown in tables respectively. 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.

Table 4: Analysis of Variance for Surface Roughness of Coated insert

Source	DF	Seq. SS	Adj. MS	F	P	Percentage Contribution
Speed	2	0.008635	0.004317	0.58	0.634	2.31
Feed	2	0.164039	0.082019	10.95	0.084	43.51
DOC	2	0.189335	0.094667	12.630	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 5: Analysis of Variance for Tool Wear for Coated insert

Source	DF	Seq. SS	Adj. MS	F	P	Percentage contribution
Speed	2	0.0014890	0.0007445	4.40	0.186	26.17
Feed	2	0.0000832	0.0000416	0.14	0.901	01.96
Doc	2	0.0037778	0.0018889	11.25	0.084	65.90
Error	2	0.0003389	0.0001694			05.96
Total	8	0.0056889				
S = 0.0130171 R-Sq = 94.04% R-Sq(adj) = 76.17%						

Table 4 shows the results of ANOVA for Surface Roughness using coated tool. 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 while the analysis from Table 5 shows the results of ANOVA for tool wear using coated tool. P-value of depth of cut (0.084) is less than 0.2. It means that depth of cut influence significantly on workpiece tool wear, TW. Depth of cut has a contribution for the tool wear is (65.90%). The next largest contribution comes from Speed as (26.17%) and from feed as (1.96%) which are not statistically significant.

The error contribution is (04.20%) and (5.96%) for surface roughness and tool wear respectively. As the percent contribution due to error is very small it signifies that neither any important factor was omitted nor any high measurement error was involved.

Table 6: Analysis of Variance for Surface Roughness for Uncoated insert

Sources	**DF**	**Seq. SS**	**Adj. MS**	**F**	**P**	**Percentage Contribution**
Speed	2	0.01100	0.00550	0.16	0.928	01.24
Feed	2	0.28146	0.14073	4.46	0.184	57.92
DOC	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%						

Table 7: Analysis of Variance for Tool Wear for Uncoated insert

Sources	**DF**	**Seq. SS**	**Adj. MS**	**F**	**P**	**Percentage Contribution**
Speed	2	0.0013500	0.0006750	2.89	0.257	18.12
Feed	2	0.0001167	0.0000583	0.14	0.938	01.56
DOC	2	0.0055167	0.0027583	11.84	0.087	74.04
Error	2	0.0004667	0.0002333			06.26
Total	8	0.0074500				
S = 0.0152753 R-Sq = 93.74% R-Sq(adj) = 74.94%						

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 while the analysis from Table 7 shows the results of ANOVA for tool wear using uncoated tool. P-value of depth of cut (0.087) is less than 0.2. It means that depth of cut influence significantly on workpiece tool wear, TW. Depth of cut has a contribution for the tool wear is (74.04%). The next largest contribution comes from Speed as (18.12%) and from feed as (1.56%) which are not statistically significant.

The error contribution is (10.97%) and (9.85%) for surface roughness and tool wear respectively. As the percent contribution due to error is very small it signifies that neither any important factor was omitted nor any high measurement error was involved.

3.2. ***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 and low tool wear.

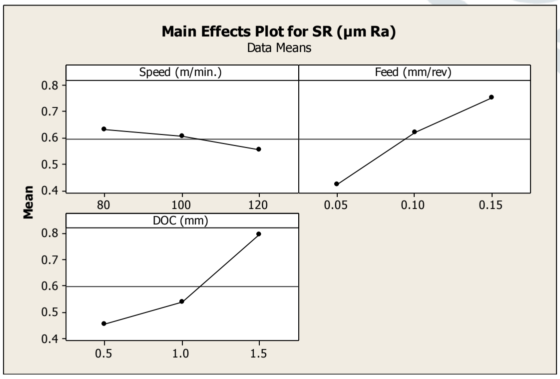

Fig. 1: Main effect plot for surface roughness using coated carbide insert

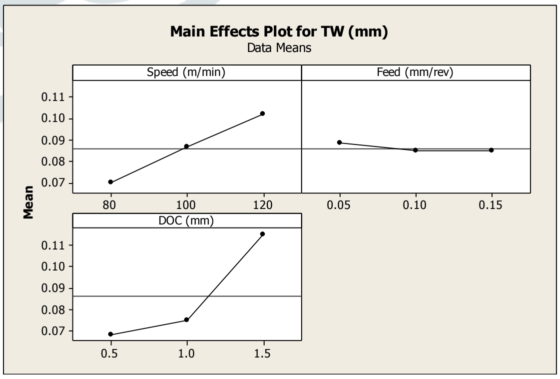

Fig. 2: Main effect plot for tool wear using coated carbide insert

Figure 1 & 2 shows the main effect plot for surface roughness and tool wear respectively for coated carbide insert. The results show that with the increase in cutting speed there is a continuous decrease in surface roughness and a continuous increase in tool wear. On the other hand, as the feed increases the surface roughness increases and the tool wear decreases upto 0.10 mm/rev and thereafter it almost remains constant. However, with the increase in depth of cut there is an increase in surface roughness and tool wear. 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. Using Figure 2 low tool wear was obtained at cutting speed of 80m/min, feed of 0.10 mm/rev and DOC of 0.5 mm.

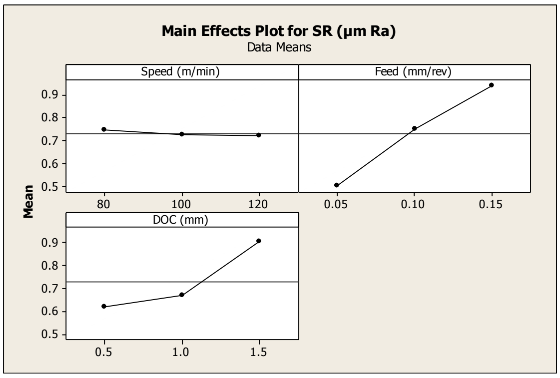

Fig. 3: Main effect plot for surface roughness using uncoated carbide insert

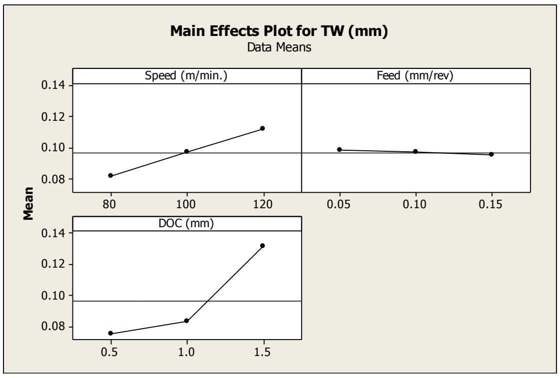

Fig. 4: Main effect plot for tool wear using uncoated carbide insert

Figure 3 & 4 shows the main effect plot for surface roughness and tool wear respectively for uncoated tool insert. The results show that with the increase in cutting speed there is a continuous decrease in surface roughness till 100 m/min and thereafter it almost remains constant and a continuous increase in tool wear is observed. On the other hand, as the feed increases the surface roughness increases and the tool wear decreases slowly. However, with the increase in depth of cut there is an increase in surface roughness and tool wear using figure 3. Low value of surface roughness was obtained at cutting speed of 100 m/min, Feed of 0.05 mm/rev and DOC of 0.5 mm. Using Figure 4 low tool wear was obtained at cutting speed of 80 m/min, feed of 0.15 mm/rev and DOC of 0.5mm.

4. COMPARATIVE STUDY OF COATED AND UNCOATED TOOL:

4.1 Comparison of Surface Roughness:

These graphs are plotted at constant speed with varying feed and depth of cut with surface roughness on Y axis and material removed on X axis.

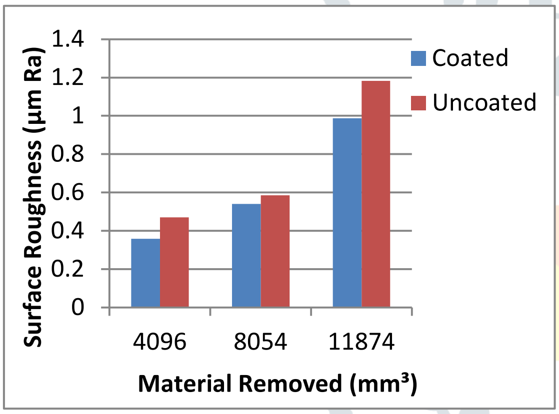

Fig. 5: Comparision of Surface roughness at constant speed of 80 m/min. with varying feed as 0.05mm/rev., 0.10 mm/rev., 0.15 mm/rev. and depth of cut as 0.5mm, 1.0mm, 1.5mm.

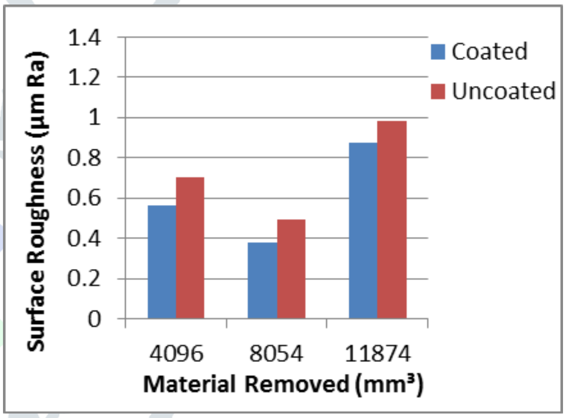

Fig. 6: Comparision of Surface roughness at constant speed of 100 m/min. with varying feed as 0.15 mm/rev., 0.05 mm/rev., 0.10 mm/rev. and depth of cut as 0.5mm, 1.0mm, 1.5mm.

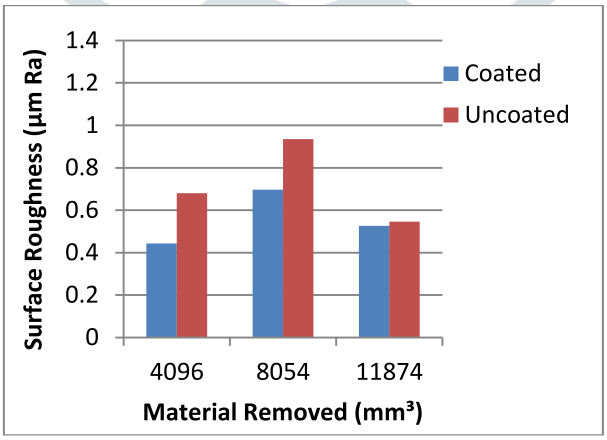

Fig. 7: Comparision of Surface roughness at constant speed of 120 m/min. with varying feed as 0.10 mm/rev., 0.15 mm/rev., 0.05 mm/rev. and depth of cut as 0.5mm, 1.0mm, 1.5mm.

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.

4.2 Comparison of Tool wears:

These graphs are plotted at constant speed with varying feed and depth of cut with tool wear on Y axis and material removed on X axis.

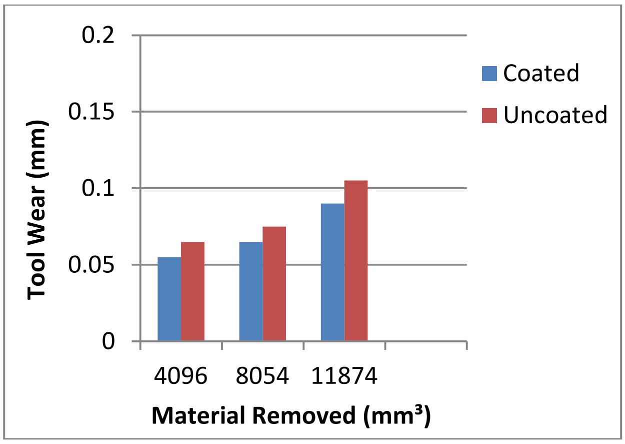

Fig. 8: Comparision of Tool Wear at constant speed of 80 m/min. with varying feed as 0.05 mm/rev., 0.10 mm/rev., 0.15 mm/rev. and depth of cut as 0.5mm, 1.0mm, 1.5mm.

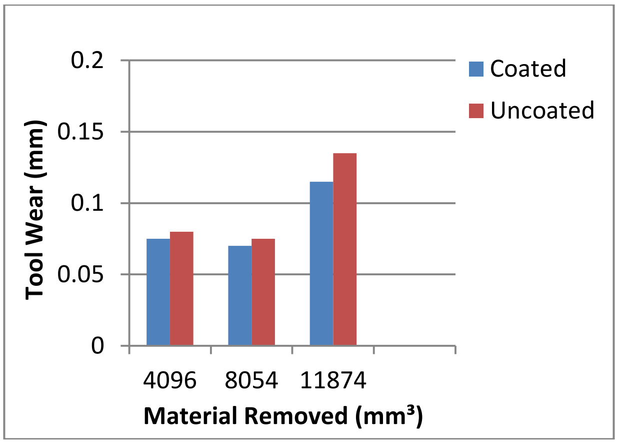

Fig. 9: Comparision of Tool Wear at constant speed of 100 m/min. with varying feed as 0.15 mm/rev., 0.05 mm/rev., 0.10 mm/rev. and depth of cut as 0.5 mm, 1.0 mm, 1.5 mm.

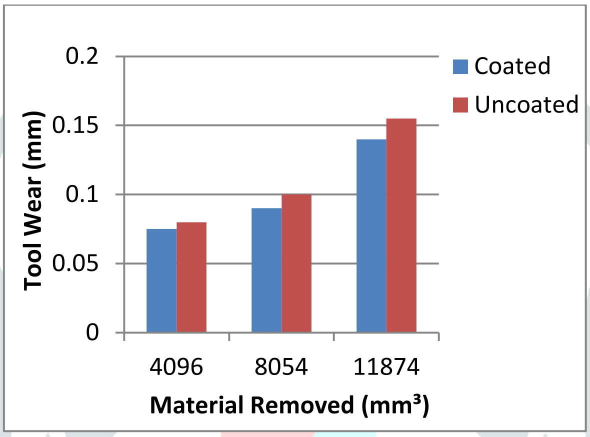

Fig. 10: Comparision of Tool wear at constant speed of 120 m/min. with varying feed as 0.10 mm/rev., 0.15 mm/rev., 0.05 mm/rev. and depth of cut as 0.5 mm, 1.0 mm, 1.5 mm

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

5. CONCLUSION:

In this paper a study for the surface roughness and tool wear for hard turning of Titanium alloy is carried out using coated and uncoated carbide inserts. From the experimental results it is observed that,

- **a)** The coated carbide inserts shows better performance compared with uncoated carbide inserts in terms of both surface roughness and tool wear.
- **b)** From ANOVA of coated carbide inserts for surface roughness it is observed that depth of cut (50.22 %) is the most significant factor.
- **c)** From ANOVA of uncoated carbide inserts for surface roughness it is observed that feed (57.92 %) is the most significant factor.
- **d)** From ANOVA of coated carbide inserts tool wear it is observed that depth of cut (65.90 %) is the most significant factor.
- **e)** From ANOVA of coated carbide inserts tool wear it is observed that depth of cut (65.90 %) is the most significant factor.
- **f)** From ANOVA of coated carbide inserts for surface roughness it is observed that depth of cut (74.06 %) is the most significant factor.
- **g)** For both inserts it is observed that with increase in depth of cut there is increase in surface roughness, with increase in speed there is decrease in surface roughness and with increase in feed there is increase in surface roughness.
- **h)** For both inserts it is observed that with increase in depth of cut there is increase in tool wear, with increase in speed there is increase in tool wear and with increase in feed there is decrease in tool wear.

6. REFERENCES:

[1] P. V. Rangrao, K. Subramanyam and C. Eswer Reddy, (2013), "Acomparitive study of tool life between ceramic and CBN cutting tools when machining 52100 steel and optimization of cutting parameters", Journal of Modern Manufacturing Technology, 6 (2), PP 109-117.

[2] C.H. Che Haron, A. Ginting and J.H. Goh, (2001), "Wear of coated and uncoated carbides in turning tool steel", Journal Of Material Process Technology, 116, PP 49-54.

[3] Ashok Kumar Sahoo and Bidydhar Sahoo, (2013), "A comparative study on performance of multilayer coated and uncoated inserts when turning AISI D2 steel under dry environment", Measurement, 46, PP 2695-2704.

[4] Samir K. Khrais, Y.J. Lin, (2007), "wear mechanisms and tool performance of TiAIN PVD Coated inserts during machining of AISI 4140 steel", Wear, 262, PP 64-69.

[5] Ashish Bhateja, Jyoti Bhardwaj, Maninder Singh and Sandeep Kumar Pal, (2013), "Optimization of Different Performance Parameters i.e. Surface Roughness, Tool Wear Rate & Material Removal Rate with the Selection of Various Process Parameters

Such as Speed Rate, Feed Rate, Specimen Wear, Depth of Cut in CNC Turning of EN24 Alloy Steel – An Empirical Approach", The International Journal of Engineering and Science, 2, PP 103-113.

[6] Ashok Kumar Sahoo and Bidydhar Sahoo, (2012), "Experimental Investigations on Machinability Aspects in Finish Hard Turning of AISI 4340 Steel Using Uncoated and Multilayer Coated Carbide Inserts", Measurement, 45, PP 2153-2165.

[7] G.S. Geng and J.H. Xu, (2009), "Experimental study on high speed machining of titanium alloy", Advanced Material Research, 69, PP 451-455.