International Journal of ChemTech Research
CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN(Online):2455-9555
Vol.11 No.02, pp 23-28, 2018

Effect of Carbide Inserts with Titanium Nitride Coating of Different Thickness on Machining Mild Steel

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Abstract : The intent of this study is to analyze the effect of different coating thickness of Titanium Nitride (TiN) on the carbide insert while machining mild steel at dry machining condition. The carbide insert was coated with Chemical Vapour Deposition (CVD) technique with varying thickness of 3µm,6µm, and 9µm. The coating thickness wasanalyzed through microstructure examination. The machining is done with varying spindle speed, feed rateand constant depth of cut. Performance of the insert is analyzed based on the surface quality of machined component. The results revealed that surface roughness of the machined mild steel component with coated insert is low when compared to the surface machined with uncoated insert and also, increase in coating thickness from 3 µm to 9 µm of coated inserts decreases the surface roughness of the mild steel component considerably.
Keywords : Dry machining, Chemical Vapour Deposition (CVD), Titanium Nitride (TiN), Mild steel, Surface roughness.

1. Introduction

In the recent manufacturing scenario machining and machinability of steel is inevitable.The surface roughness is one of the most significant product quality attribute and has the hugesignificance on the functional behaviour of the machined component[1-2]. The poor surface quality fails to satisfy functional requirements of the products, while extremely high surface quality causes high production costs and low overall productivity[3]. Hence, the improved surface quality and the economics of the manufacturing operation are becoming very important consideration to produce the finished products[4].

The Titanium Nitridecoated tool used in industries is constantly facing the very common industrial challenge of reducing the cost of machined parts and at the same time improving the quality of the machined surface.The benefits of advanced Titanium Nitridecoating arehigher wear resistance, higher hardness, low friction at the chip tool contact; highchemical and thermal stability. The machined surface quality with the coated cutting tool insert couldimprove by avoiding any built-up edge due to the reduced friction between the tool and workpiece. Based on the abundant advantages of surface coating Titanium Nitride and the requirement of industrial development and requirement, it is necessary to develop Titanium Nitride carbide tool. Based on these driving forces, it is necessary to do surface coat Titanium Nitride on carbide cutting tool to give agoodperformance on machining[5-7].

International Journal of ChemTech Research, 2018,11(02): 23-28.

DOI= http://dx.doi.org/10.20902/IJCTR.2018.110204

The researchers [6] have studied surface roughness characteristics in turning operation of EN-31 alloy steel with TiN coated tungsten carbide tool under different cutting parameters.The researchers [7]have developed a surface roughness prediction model for mild steel machined by TiN-coated tungsten carbide cutting tools with the help of Response Surface Methodology.The researchers [8] have studied the effect of cutting parameters namely speed, feed and depth of cut on the surface roughness of EN24 steel when turned with TiC coated tungsten carbide inserts.The researchers [9] have investigated the influence of cutting parameters such as cutting speed, feed rate and depth of cut on surface roughness of hardened AISI 4140 steel turned with Al_2O_3 and TiCN mixed ceramic tool.Taguchi's robust orthogonal array design method is suitable for analysis of the surface roughness during machining operation[10-12].

2. Materials and Methods

Initially, a carbide insert was purchased from the market and coated with TiN through Chemical Vapour Deposition (CVD) technique.CVDis a chemical process used to produce high quality, high-performance solid materials. Usually, in CVD method the substrate is exposed to one or more volatile precursors, which react or decompose on the substrate (insert) surface to produce the desired deposit. Frequently, volatile by-products are also produced, which are removed by gas flow through the reaction chamber. The CVD method that is followed to coat the TiN over the carbide insert is shown in Figure 1and Figure 2, Figure 3 exemplifies the inserts with and without TiN coating.

Figure 1:Chemical vapour deposition of TiN over carbide insert

Figure 2:Uncoated carbide insert **Figure 3:TiN Coated carbide insert**

The experiments were done in a CNC machine centre (LMW smart junior) under dry condition at different spindle speed and feed rate. A mild steel bar of 40mm diameter with ahardness of 195.6HB was utilized as theworkpiece. The experiments were planned based on Taguchi's L_8 orthogonal array. The surface roughness of the machined components was measured by using asurface roughness tester (Mitutoyo SJ201) and theaverage value is taken for further analysis.Figure 4 shows the CNC turning operation and Figure 5 illustrates the mild steel bars after machining while Figure 6 shows the surface roughness measurement.The control factors and its corresponding levels are given in Table 1.

Table 1: Control factor and levels

Control factors	**Notation**	**Level 1**	**Level 2**	**Level 3**	**Level 4**
Coating Thickness (µm)	C	0	3	6	9
Spindle Speed (rpm)	N	3000	6000	-	-
Feed (mm/rev)	f	0.3	0.6	-	-

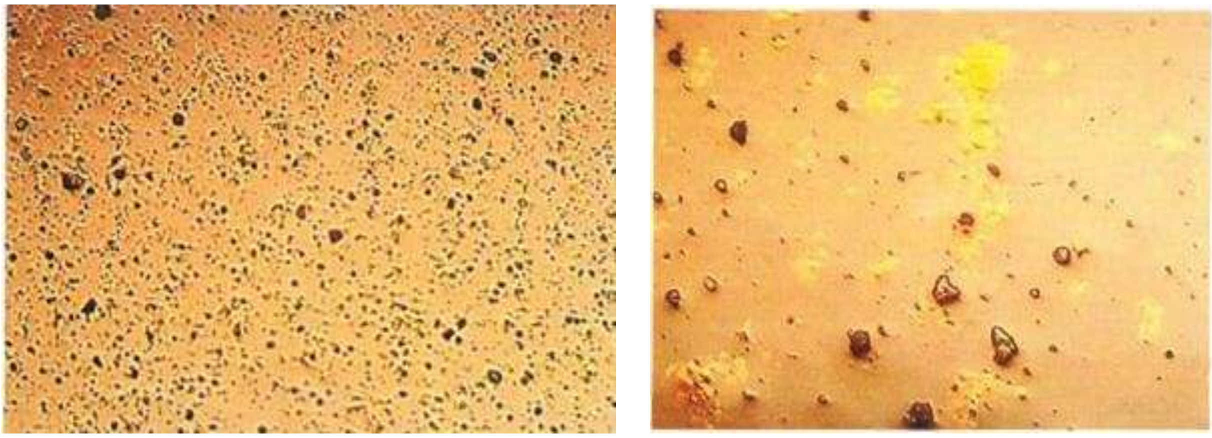
Figure 4: Turning of mild steel

Figure 5:Machined workpiece

Figure 6:Surface roughness measurement

3. Result and Discussion

3.1. Microstructure



(a)100X magnification **(b)500X magnification**

Figure 7: Microstructure of theTiNcoated carbide insert

Figure 7 presents the microstructure of coated insert at low (100X) and high (500X) magnification. It can be clearly identified from the figure that the TiN coating applied through CVD technique is uniform.

3.2. Surface Roughness

The L_8 orthogonal array and the measured averagesurface roughness (Ra) values and their corresponding signal to noise (S/N) ratio valuesis given inTable 2. As the aim is to get lower surface roughness, smaller the better criterion was selected to calculate the S/N ratio for this study.

Table 2: L_8 orthogonal array with surface roughness and S/N ratio

Ex. No.	Coating thickness (µm)	Spindle Speed (rpm)	Feed rate (mm/rev)	Mean Surface roughness, Ra (µm)	S/N Ratio
1	0	3000	0.3	1.264	-2.03494
2	0	4000	0.6	1.309	-2.33879
3	3	3000	0.3	0.984	0.14010
4	3	4000	0.6	1.031	-0.26517
5	6	3000	0.6	0.749	2.51036
6	6	4000	0.3	0.656	3.66192
7	9	3000	0.6	0.641	3.86284
8	9	4000	0.3	0.553	5.14550

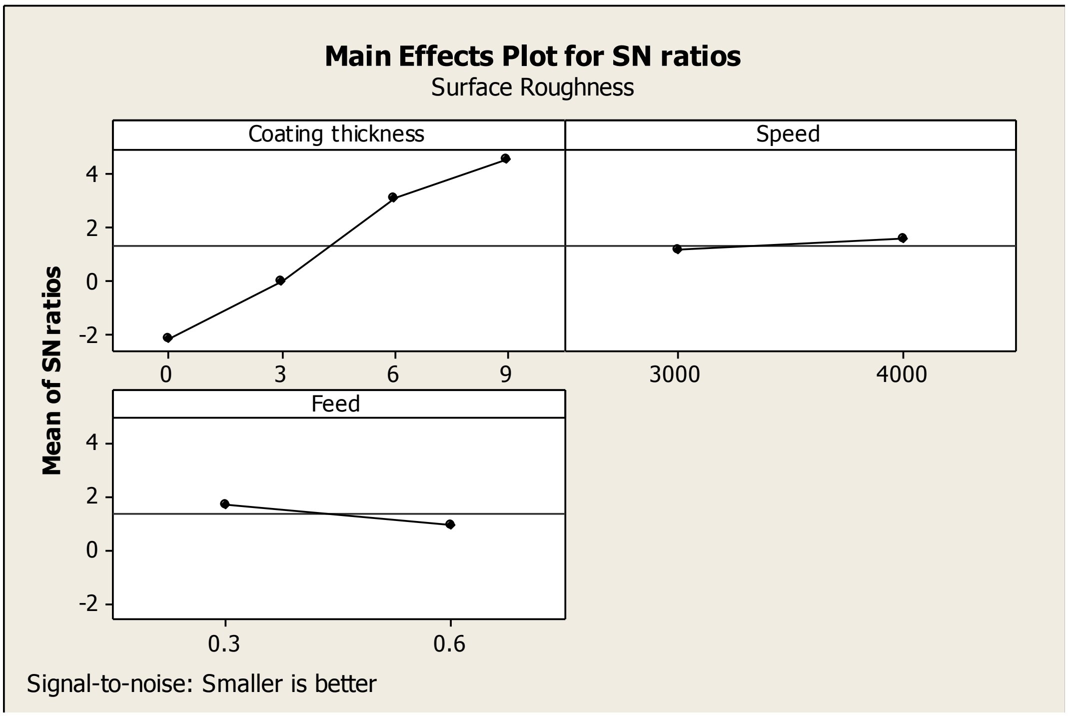


Figure 8 : Effect of input parameters on surface roughness

Main effect plot for surface roughness is shown inFigure 8confirms that the roughness of the machined surface is greatly reducing when the coating thickness is increased. Hence it is proved that the addition of TiN coating over the carbide insert will increase the surface finish of the product machined.

Table 3, from the main effect table, it is evident that the coating thickness has more influence on surface roughness followed by feed rate and spindle speed.

Table 3: Mean table for Surface roughness (SN ratio)

Level	Coating thickness	Spindle speed	Feed rate
1	-2.18687	1.11959	1.72814
2	-0.06254	1.55086	0.94231
3	3.08614	-	-
4	4.50417	-	-
Delta	6.69104	0.43127	0.78584
Rank	1	3	2

ANOVA table for surface roughness shown in Table 4 confirms that all the three considered parameters have significant influence over the response variable. Since the ANOVA is performed at 95% confidence level, the parameter which has ‘p’ value less than 0.05 is considered as significant.

Table 4:ANOVA for surface roughness

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Coating thickness	3	0.58349	0.58349	0.19450	53653.92	0.0001
Spindle speed	1	0.00099	0.00099	0.00099	273.14	0.0040
Feed rate	1	0.00932	0.00932	0.00932	2569.97	0.0001
Error	2	0.00001	0.00001	0.00000		
Total	7	0.59380				

A regression equation is also developed for predicting surface roughness based on the experimental values through thegeneral linear model. The developed regression equation is,

$$\mathbf{Ra = 1.2299 - 0.0791167C - 2.225 \times 10^{-005}N + 0.2275\, f} \quad \mathbf{(1)}$$

4. Conclusion

Based on the surface roughness test conducted on mild steel during turning operation with varying coating thickness on carbide insert under dry machining condition, this research work is concluded with the following key points:

1. Coating of TiN over the insert increases the performance of the tool *i.e.* surface roughness decreases andalso further increase in coating thickness decreases the surface roughness value.
2. The spindle speed and feed rate have less effect over surface roughness than the coating thickness. Increase in the speed decreases the roughness while increment in feed amplifies the roughness of the machined component.
3. From the mean effect table, it is evident that TiN Coating thickness has asignificant effect on surface roughness followed by feed rate and surface roughness.
4. From the ANOVA results, it is evident that the error associated is less than 5%, so the mathematical model developed through regression analysis could be applied to any machining condition.

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