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EXPERIMENTAL ANALYSIS OF PVD AND CVDAPPLIED COATED CUTTING TOOL INSERT BASEDON SURFACE ROUGHNESS ANDTOOL WEAR FOR TURNING OF EN9 STEEL

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Abstract: This work has been focus on the coated tool material of PVD and CVD by turning of using EN9 medium carbon steel material. Analysis will be done based on surface roughness of workpiece Material and tool flank wear also comparison will be done between PVD and CVD coating tool material. The statistical tools like Taguchi, ANOVA and Regression analysis will be used for optimization of cutting condition based on surface roughness and prediction equation will be found between input and output variables. All the literature survey and design of experiments are based on above matters in the study.

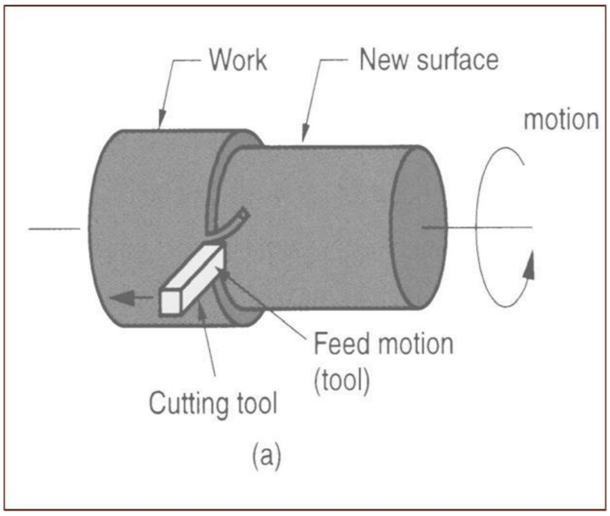
Keywords: CNC turning machine, Regression Analysis, Tool Wear, Surface roughness

I. INTRODUCTION

Turning is used to reduce the diameter of the work piece usually to a specified dimension, and to produce a smooth finish on the metal.Coatings are frequently applied to carbide tool tips to improve tool life or to enable higher cutting speeds. Coated tips typically have lives 10 times greater than uncoated tips. Common coating materials include titanium nitride, titanium carbide and aluminum oxide, usually 2 - 15 micro-m thick.The techniques used for applying coatings include chemical vapor deposition 5(CVD) plasma assisted CVD and physical vapor deposition (PVD).PVD means Physical Vapour Deposition it is a process carried out in high vacuum at temperature between 150 to 500.The most common of these PVD coating processes are evaporation (using cathodic arc or electron beam sources) and sputtering (using magnetic enhanced sources).All of these processes occur in vacuum at working pressure (typically 10-2 to 10-4 mbar) and generally involve bombardment of the substrate to be coated with energetic positively charged ions during the coating process to promote high density. Additionally, reactive gases such as nitrogen, acetylene or oxygen may be introduced into the vacuum.Chemical Vapor Deposition (CVD) is an atmosphere controlled process conducted at elevated temperatures (~1925° F) in a CVD reactor. During this process, thin-film coatings are formed as the result of reactions between various gaseous phases and the heated surface of substrates within the CVD reactor.$TiCl_4 + N_2 + H_2$ 1000° C → $TiN + 4 HCl + H_2$. Titanium carbide (TiC) is formed as the result of the following chemical reaction: $TiCl_4 + CH_4 + H_2$ 1030° C → $TiC + 4 HCl + H_2$.

A. Design of Experiment

Design of experiments was developed in the early 1920s by Sir Ronald Fisher at the Rothamsted Agriculture field Research Station in London, England. His initial experiments



were concerned with determining the effect of various fertilizers on different plots of land. The final condition of the crop was not only dependent on the fertilizer but also on the number of other factors (such as underlying soil condition, moisture content of the soil, etc.) of each of the respective plots. Fishers used DOE which could differentiate the effect of fertilizer and the effect of other factors. Since that time the DOE has been widely accepted in agricultural as well as Engineering Science. Design of experiments has become an important methodology that maximizes the knowledge gained from experimental data by using a smart positioning of points in the space. This methodology provides a strong tool to design and analyze experiments; it eliminates redundant observations and reduces the time and resources to make experiments. We have used factorial design, and used full factorial design. For a full factorial design, if the numbers of levels are same then the possible design N is

$$N=L^m$$

Where, L = number of levels for each factor, and m= number of factors.

II. DOE FOR CNC TURNING

Table 1: Factors and their levels in CNC Straight Turning

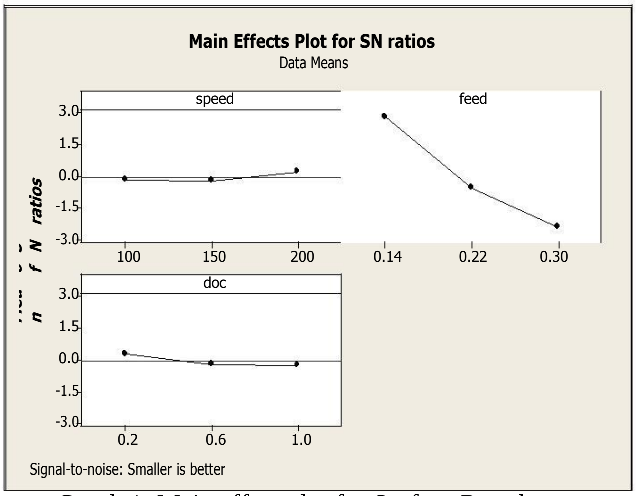
Process parameter	Process designation	Level 1	Level 2	Level 3
Cutting Speed(m/min)	A	100	150	200
Feed(mm/rev)	B	0.14	0.22	0.30
Depth of cut (mm)	C	0.2	0.6	1.0

A. Experimental setup

In order to achieve the goal of this experimental work the cutting tests were carried out in a SUPERCUT 6N CNC turning center. The CNC turning centre has 5.5 kw / 7 kw spindle motor power and a maximal machining diameter of 165mm, maximal spindle speed of 4000 rpm, spindle speed range 40 to 4000 rpm and maximal turning length 350mm.

Table 2: Data obtained from experimental work for surface roughness

Cutting speed (m/min)	Cutting Speed (rpm)	Feed (mm)	Depth of cut (mm)	Surface Roughness
100	996	0.14	0.2	0.70
100	996	0.14	0.6	0.72
100	996	0.14	1.0	0.85
100	996	0.22	0.2	0.94
100	996	0.22	0.6	1.20
100	996	0.22	1.0	1.07
100	996	0.30	0.2	1.35
100	996	0.30	0.6	1.29
100	996	0.30	1.0	1.32
150	1493	0.14	0.2	0.71
150	1493	0.14	0.6	0.73
150	1493	0.14	1.0	0.69
150	1493	0.22	0.2	1.0
150	1493	0.22	0.6	1.07
150	1493	0.22	1.0	1.12
150	1493	0.30	0.2	1.45
150	1493	0.30	0.6	1.37
150	1493	0.30	1.0	1.49
200	1991	0.14	0.2	0.68
200	1991	0.14	0.6	0.72
200	1991	0.14	1.0	0.75
200	1991	0.22	0.2	0.99
200	1991	0.22	0.6	1.15
200	1991	0.22	1.0	1.09
200	1991	0.30	0.2	1.21
200	1991	0.30	0.6	1.26
200	1991	0.30	1.0	1.15



Graph 1: Main effect plot for Surface Roughness

According to this main effect plot fig.5.1, the optimal conditions for minimum surface roughness are:

- Cutting speed at level 3 (200 m/ min),
- Feed rate at level 1 (0.14 mm/ rev),
- Depth of cut at level 1 (0.2 mm)

Table 3: For Cutting length vs Tool flank wear

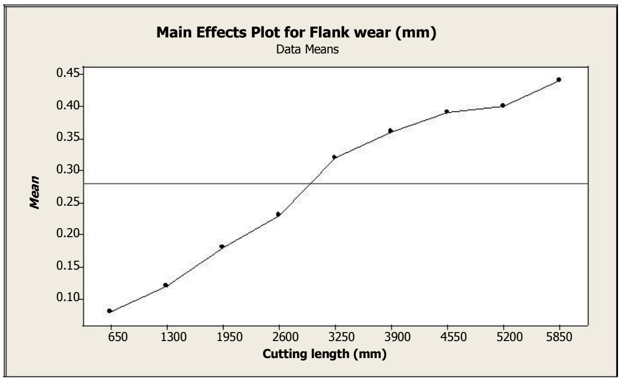
Cuuting length	Tool flank wear (PVD)	Tool flank wear (CVD)
650	0.10	0.08
1300	0.16	0.12
1950	0.23	0.18
2600	0.32	0.23
3250	0.36	0.32
3900	0.39	0.36
4550	0.41	0.39
5200	0.46	0.40
5850	0.48	0.44

III. RESULTS & DISCUSSION

Table 4: Response Table for Signal to Noise Ratios (Smaller is better)

Level	**S**	**F**	**D**
1	-0.16	2.77	0.28
2	-0.22	-0.56	-0.21
3	0.21	-2.39	0.25
Delta	0.44	5.16	0.53
Rank	3	1	2

We can analyze from the main effects plot for S/N ratio for surface roughness figure 5.1, the surface roughness appears to be an almost linear increasing function of feed rate and decreasing function of cutting speed. Thus in order to reduce the level of surface roughness, feed rate (F) should be set to its lowest level (0.14 mm/rev) and speed (S) to its highest level (200 m/min). Also, high level (1.5mm) or low level (0.2mm) of depth of cut may be preferred, while the effect of D has not been found statistically significant. I have used depth of cut of 0.5 mm.



Graph 2: Flank wear v/s Cutting length of CVD coated cutting tool insert

Table 5: ANOVA for Surface roughness versus Flank wear

Analysis of Variance					
Source	DF	SS	MS	F	P
Regression	1	6.90687	6.90687	435.482	0.0000001
Residual Error	7	0.11102	0.11102		
Total	8	7.0179			
S = 0.125938	R-Sq= 98.42 %	R-Sq(adj) = 98.19%			

From table 5.12, it can be shown that a null hypothesis (Ho) that the tool flank-wear has no effect on the surface roughness and an alternative hypothesis (Ha) that the tool flank wear has an effect on surface roughness were used. Again using a α-value of 0.05, the null hypothesis is rejected in favor of the alternative hypothesis since the P value for this regression is 0.000 which is less than α-value of 0.05. And so it can be concluded that the flank wear has a significant effect on surface roughness.

IV. CONCLUSION

Machining performance of cutting tools are made by conducting actual machining tests. This study evaluates the machining performance of three commercially available cutting tool inserts in turning EN-9 steel round bar. CVD coated and PVD coated tools were examined and their flank wear and the resultant machined work piece surface finish were analyzed.The tool coatings were found to improve the wear resistance of the cutting tool. This was shown by the decrease in wear on the flank face of the coated tools compared to that of the uncoated tool. The wear of the CVD coated tool was around 19% lower than the wear observed on the uncoated tool. PVD coated tool showed a decrease of around 27% compared to the uncoated tool. PVD coated tool also shows the flank wear decrease of around 10% compared to CVD coated tool. The decrease in wear was due to the wear resistance properties of the TiN, TiC and Al materials and the high chemical stability of their layer.In the case of the machined surface roughness, PVD and CVD coated tools produced lower surface roughness than that was produced by the uncoated tool. The PVD coated tool produced the lowest average surface roughness after turning with a decrease of around 24% compared to the uncoated tool. The CVD coated tool produced the second lowest average surface roughness with a decrease of around 13% compared to the uncoated tool. While on the other hand, the PVD coated tool produced the decrease average surface roughness with of around 12.5% compared to CVD coated tool.From the day cost analysis, cost of uncoated tool is comparatively low but surface roughness is higher compared to CVD and PVD coated tools. If required range of surface roughness is 4 to 6 µm or little more than uncoated tool can be used.If required range of surface roughness is from 2 to 4 µm then PVD coated cutting tool is better than uncoated and CVD coated cutting tool insert.

V. FUTURE SCOPE

- Similar work can be carried out by changing the process parameters or by changing value of process parameters as well as by changing the material for experimental purpose.
- Investigation of different cooling environment on Surface Roughness and Tool Wear in turning of EN 9.
- Influence of process parameters on tool wear in turning of EN 9.
- Machining performance of various cutting tool (Coated and Uncoated) in turning of EN 9.

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