PERFORMANCE EVALUATION OF TiN COATED CARBIDE INSERT FOR OPTIMUM SURFACE ROUGHNESS IN TURNING OF AISI 1045 STEEL

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Abstract

In manufacturing industry, beside the dimensional and geometric tolerance of a component, surface quality is most commonly specified requirements. Surface roughness plays an important role in the performance of the component. This paper presents a study of the influence of the cutting parameters on the surface roughness during the turning of AISI1045 steel with TiN coated carbide tool. The design of experiments based on the Taguchi technique. The objective was to optimization of the machining parameters as cutting speed, feed rate and depth of cut for surface roughness. Main effect plots are generated and analyzed to find out the relationship between them. Afterwords a confirmation test were performed to make a comparison between the predicted results and the theoretical results.

Keywords: *TiN carbide insert, AISI 1045 alloy steel, Taguchi method, Surface roughness, ANOVA.*

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1. INTRODUCTION

Maintaining the economic production with optimal use of resources is of prime concern for the manufacturing industries. In machining process, various parameters are involved and challenges that come across are to find out the optimal parameters for the desired product quality. In today's manufacturing industries, special attention is given to dimensional accuracy, geometric tolerance and surface finish. beside the dimensional and geometric tolerance of a component, surface quality is most commonly specified requirements. Surface roughness plays an important role in the performance of the component. The quality of surface is an important parameter to evaluate the productivity of machine tools as well as machined components. The surface roughness is used as the critical quality indicator for the machined surface. The quality of the work piece (either roughness or dimension) are greatly influenced by the tool material, tool geometry, cutting conditions, machining process, work piece material, chip formation, tool wear and vibration during cutting[1]. A lot of effort has been done to observe the critical parameters which affect the surface roughness. The manufacturing industries are trying to decrease the cutting costs, improve the quality of the machined parts and machine more difficult materials.

Machining efficiency is improved by reducing the machining time with high speed machining. But the chemical stability and the softening temperature of the tool material limits the cutting speed. While cutting ferrous and hard to machine materials such as cast iron, super alloys and steels, softening temperature and the chemical stability of the tool material limits the speed of cutting. Therefore, it is necessary for tool materials to possess sufficient inertness and good high-temperature mechanical properties. While many ceramic materials such as TiC, Al2O3 and TiN possess hot hardness, they have lower fracture toughness than that of conventional tool materials such as tungsten carbides and high-speed steels. The machining of hard and chemically reactive materials at higher speeds is improved by depositing single and multi layer coatings on conventional tool materials to combine the beneficial properties of ceramics and traditional tool materials. Coatings are diffusion barriers, which prevent the interaction between chip formed during the machining and the cutting material itself. The compounds which make up the coatings used are extremely hard and so they are very abrasion resistive. Main constituents of coating are Titanium Carbide (TiC), Titanium Nitride (TiN), Titanium Carbonitride (TiCN) and alumina (Al2O3). All these compounds have low solubility in iron and they enable inserts to cut at much higher rate. The use of coating materials to enhance the performance of cutting tools is not a new concept. Coated hard metals have brought tremendous increase in productivity since their introduction in 1969 and had an immediate impact on the metal cutting industries [2]. Due to their significantly higher hardness, carbide-cutting tools are widely used in the manufacturing industries today than high-speed steels. Coated and uncoated carbides are widely used in the metal working industry and provide the best alternative for most turning operations [3]. Due to their heat resistance, cemented carbides can be used in very hot applications and all types of PVD and CVD processes can be used to deposit coatings [4] It is necessary for tool materials to possess high temperature strength. While many ceramic materials such as TiC, Al2O3 and TiN possess high hot strength, they are lower in fracture toughness than that of conventional tool materials such as high-speed steels and cemented tungsten carbides. The machining of chemically reactive and hard materials at higher speeds is improved by depositing single and multi layer coatings on conventional tool materials to combine the beneficial properties of ceramics and traditional tool materials [5].

2. LITERATURE REVIEW

I.Yu. Konyashin [6] examines the effect of TiN and TiC coating on the cemented carbide tools obtained by physical vapour deposition (PVD). He investigated that the PVD-CVD coated carbide has longer tool life in turning as compared to conventially coated inserts.PVD technology allows elimination of the decarburization or damage of the cemented carbide substrate and also used for depositing special barrier underlayer before deposition of the conventional coating. P.C Jindal et.al. [7] observed that TiAlN coated tools showed the best metal cutting performance, followed by the TiCN and TiN coated tools According to Maan Aabid Tawqif [8] (TiN,TiC) coated cutting tools gave best results for surface finish compared with TiN, TiC, Al2O3, TiN and all uncoated tool, for selected machining conditions. The experimental results also showed that, when the cutting speed is increased and feed rate is reduced, the values of surface roughness is decreased for uncoated tool insert, for single coated layer insert(TiN), for double coated layer insert (TiN/TiC) and for triple coated layer insert (TiN/Al2O3/TiC). J.A.Ghani et.al.[9] investigated the wear mechanism of TiN-coated carbide and uncoated cermets tools at various combinations of feed rate, depth of cut and cutting speed for hardened AISI H13 tool steel. They observed that the time taken for the cutting edge of TiN-coated carbide tools to initiate cracking and fracturing is longer than that of uncoated cermets tools, especially with the combinations of feed rate, depth of cut and high cutting speed and at the combinations of feed rate, depth of cut and low cutting speed, the uncoated cermets tools show more uniform and gradual wear on the flank face than that of the TiN-coated carbide tools. Renato Francoso de A vila et.al. [10] tested the performance of uncoated and coated carbide tools with a 3μm thick monolayer of TiN when continuous turning AISI 8620 steel. Their results indicate that two distinct crater wear rates are present when machining using coated cutting tools, whereas a higher and single wear rate was identified for the uncoated inserts. J. Rech [11] found that coatings exhibit to the best tribological improvements when uncoated tools are compared. Four complementary methods were used to qualify the performance of the tribological system with the purpose of reaching a better global understanding of the capability of coatings, cutting forces, interface temperature, chip formation mechanisms,. TiN coatings have shown the best tribological improvements compared to uncoated tools. Shamshul Asri Bin Mohd Yusuf [12] analysis the performance of TiC coated carbide cutting tool in turning AISI 1045 steel. In his study he presented the flank wear characteristics of titanium carbide (TiC) as coated material on cemented carbide tool during machining AISI 1045 steel in dry machining. Leonardo R. Silva et.al. [13] in his research work, investigated the effect of cutting speed on cutting forces and surface roughness when dry precision turning AISI 1045 steel using coated and uncoated cemented carbide tools. The results showed, the turning force components tend to decrease or remain practically stable as cutting speed increased.

3. DESIGN OF EXPERIMENTS

The objective of this study to performance evaluation of coated carbide inserts for optimum surface roughness of AISI 1045 steel. In the present work Taguchi's parameter design approach is used to study the effect of process parameters-cutting speed, feed rate, depth of cut on surface roughness while turning of AISI 1045 steel.

Taguchi Method are statistical approach developed by Genichi Taguchi to improve the quality of manufactured products, and more recently also applied to engineering, biotechnology, marketing and advertising[14][15][16][17]. Taguchi recommends orthogonal arrays (OA) for lying out of experiments The optimum condition is identified by studying the main effects of each of the parameters. The analysis of variance (ANOVA) is the statistical treatment most commonly applied to the results of the experiments in determining the percent contribution of each parameter against a stated level of confidence. Detailed study of ANOVA table for a given analysis helps to determine which of the parameters need control [18].

Taguchi's work includes three principle contributions to statistics

1. A specific loss function
2. The philosophy of off-line quality control
3. Innovations in the design of experiments.

The Taguchi-based experimental design used in this study is an L9 orthogonal array.

Signal-to-Noise ratios (S/N ratio)

The parameters that influence the output can be categorized into two classes, namely controllable (signal) factors and uncontrollable (or noise) factors. S/N ratio is used to measure the quality characteristic deviating from the desired value. The S/N ratios for surface roughness are calculated as given in equation.

$$LSB = [1/n \sum_{i=1}^{n} 1/y^2_{sr(i)}]$$

S/N ratio for Ra = -10 log10 (LSB)

4. EXPERIMENTAL DETAILS

The experiments were conducted on a CNC Lathe machine (HAAS USA TL) installed at Central Institute of Plastic Engineering and Technology, Murthal (Sonepat), India (Figure1.).

Model :	TL
Make :	HAAS-USA
Program Controller :	HAAS
Max. Holding Diameter :	20mm
Max. Turning Length :	600mm
Spindle Speed :	50-5000 rpm
Feed rate range :	0.0025-100mm/rev
Accuracy :	10microns

In this experiment VBMT 160408 TN2000 coated carbide insert was used as cutting tool.

Insert shape	:	Rhombic 35◦
Normal clearance	:	5◦
Tolerance of nose height	:	± 0.08mm to ±0.18mm
Tolerance of inscribed circle:		±0.05mm to ±0.15mm
Tolerance of thickness	:	±0.13mm
Dia of inscribed circle (insert size):		9.525mm
Insert thickness	:	4.76mm
Insert corner radius	:	0.8mm
ISO	:	HC-P20
Coating	:	CVD TiN

Work piece material AISI 1045 with a diameter of 50mm and 200mm length was used as work piece. Chemical composition of material is given in Table1

Table: 1 Chemical Composition Of AISI 1045 Alloy Steel

Carbon %	Manganese%	Phosphorus%	Sulphur %	Silicon%	Iron%
0.43 to 0.50	0.60 to 0.90	0.04 max.	0.050 max.	0.10 to 0.60	Balance

Figure 1 CNC lathe used for Experimentation

The measurement of surface characteristics (surface roughness) of the turned specimen was accomplished under Mitutoyo Surftest SJ-201 P/M. The unit of Ra is in µm. Ra can be directly obtained after machining the work piece. The average value of Ra is recorded for each number of trials in order to obtain the accurate result. The length of measurement for each specimen will be 60mm.

Figure 2 Surface roughness measurement device-Mitutoyo Surf test SJ-201 P/M

The selection of parameters of interest was based on some experiment preliminary .The following process parameters were thus selected for the present work:

a) Cutting speed – (A),
b) Feed rate – (B),
c) Depth of cut – (C),

The feed rate and depth of cut were selected from within the range of parameters for turning. The coated carbide insert chosen was TiN coated carbide insert to find the best optimum speed, feed and depth of cut among the chosen one.

Table 2: Selection of process parameters with codes, units and levels

Parameter (Control factors)	Code	Level 1	Level 2	Level 3
Cutting speed (m/min)	A	150	200	250
Feed rate (mm/rev)	B	0.1	0.2	0.3
Depth of cut (mm)	C	0.75	1.50	2.25

Each three level parameter has 2 degree of freedom (DOF) (Number of level – 1), the total DOF required for three parameters each at three levels is 6[=3x (3-1)]. As per Taguchi's method the total DOF of the OA must be greater than or equal to the total DOF required for the experimentation. So an L9 OA (a standard 3- level OA) having 6(=9-3) degree of freedom was selected for the present analysis. Minitab 15 software was used for graphical analysis of the obtained data.

Sr. No.	Cutting Speed (m/min)	Feed Rate (mm/rev)	Depth Of Cut (mm)	Ra 1 (µm)	Ra2 (µm)	Ra3 (µm)	Mean (µm)	S/N RATIO (db)
1	150	0.1	0.75	2.35	2.43	2.51	2.43	-7.7121
2	150	0.2	1.50	3.96	3.89	4.03	3.96	-11.9539
3	150	0.3	2.25	5.82	5.64	5.73	5.73	-15.1631
4	200	0.1	1.50	3.20	3.25	3.15	3.20	-10.1030
5	200	0.2	2.25	3.88	4.02	3.95	3.95	-11.9319
6	200	0.3	0.75	3.67	3.60	3.75	3.67	-11.2933
7	250	0.1	2.25	2.32	2.38	2.35	2.38	-7.5315
8	250	0.2	0.75	2.40	2.33	2.47	2.40	-7.6042
9	250	0.3	1.50	3.90	4.06	3.98	3.98	-11.9977

Table 3. Result of the L9 OA experiment using TiN coated carbide insert

5. RESULT AND DISCUSSION

5.1 Analysis of Raw Data and S/N Ratios:

The analysis of variance was carried out for a 95% confidence level. The ANOVA Tables 4 shows that, the F value corresponding to all parameters are greater than the tabulate value of F0.05. The main purpose of the analysis of variance is to investigate the influence of design parameters on optimal surface finish by indicating the parameters that significantly affect the quality characteristics of the machined surfaces. The given analysis provides the relative contribution of machining parameters in controlling the response of machining performance criteria i.e. surface roughness height Ra during AISI 1045 alloy steel turning. Table 4 shows that the cutting speed, feed, and depth of cut are responsible and have influence on surface roughness height Ra while turning with TiN coated carbide inserts. The influence of feed is the most significant as according literature review. And the influence of depth of cut is significant and cutting speed is less influencing factor as compare to other on the surface roughness height Ra during turning of AISI 1045 steel.

Table 4 ANOVA for TiN coated carbide insert, using Adjusted SS for Tests

Source	DF	SS	MS	F-Ratio	F-Ratio table	P
Cutting speed	2	1.9137	0.9568	6.14	3.49	0.140
Feed rate	2	4.8391	2.4195	15.52	3.49	0.061
Depth of cut	2	2.2766	1.1383	7.30	3.49	0.120
Error	2	0.3118	0.1559			
Total	8	9.3412				

S=0.394814 R-Square=96.66% R-Square (Adj)=86.65%

Where,
DF - degrees of freedom,
SS - sum of squares,
MS - mean squares (Variance),
F- ratio of variance of a source to variance of error,
Probability < 0.05 - determines significance of a factor at 95% confidence level.

The Ra (mean response variable) effect table under the array in Table 5 indicates the mean of the response variable means for each level of each control factor. This specifies the mean surface roughness value that each level of each control factor produced during this experiment. The S/N effect table under the array Table 6 indicates the mean of the S/N values for each level of each control factor.

Table 5: Response Table for Means using TiN coated carbide insert

Level	Cutting Speed	Feed rate	Depth of cut
1	4.040	2.670	2.833
2	3.607	3.437	3.713
3	2.920	4.460	4.020
Delta	1.120	1.790	1.187
Rank	3	1	2

Table 6: Response Table for S/N Ratios for TiN coated carbide insert

Level	Cutting speed	Feed rate	Depth of cut
1	-11.610	-8.449	-8.870
2	-11.109	-10.497	-11.352
3	-9.044	-12.818	-11.542
Delta	2.565	4.369	2.672
Rank	3	1	2

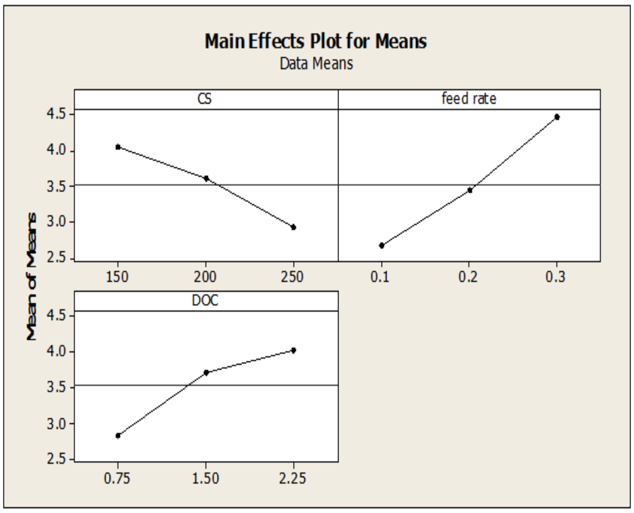

Figure3: Main effect plot for means using TiN coated carbide insert

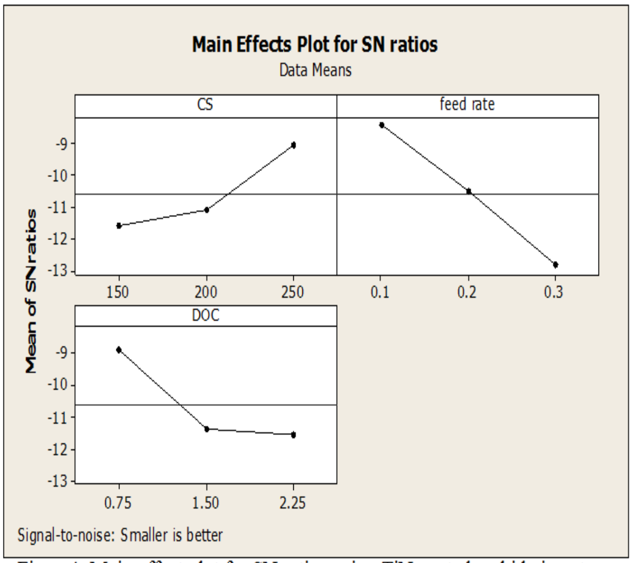

Figure4: Main effect plot for SN ratios using TiN coated carbide insert

Predicted values for TiN coated carbide

Mean
1.37889
Factor levels for predictions

CS	FR	DOC
250	0.1	0.75

6. CONFIRMATION EXPERIMENTS

Sample #	Ra (µm)
1	1.456
2	1.460
3	1.479
4	1.454
5	1.461
Mean Ra(µm)	**1.462**

CONCLUSIONS

The present research can be concluded in the following steps:
1. Taguchi design of experiment technique can be very efficiently used in the optimization of machining parameters in metal cutting processes.
2. This research found that the control factors had varying effects on the response variable, with feed rate having the highest effects for TiN coated carbide insert.
3. Optimum parameter setting for surface roughness for TiN is obtained at a cutting speed of 250m/min, feed rate 0.1mm/rev. and depth of cut 0.75mm.
4. The measurement of the work pieces in this confirmation run led to the conclusion that the selected parameter values from this process produced a surface roughness that was much lower than the other combinations tested in this study.
5. The predictive value for TiN coated carbide tool is 1.37889µm.

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