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Original Research Article

ESTIMATION OF SURFACE QUALITY IN MACHINING OF HARDNED MATERIAL USING COATED CARBIDE TOOL

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Abstract

In this study, an attempt has been made to evaluate the performance of multilayer coated carbide inserts during dry turning of hardened AISI 4340 steel (47 HRC). The effect of machining parameters (depth of cut, feed and cutting speed) on surface roughness parameters (Ra and Rz) were investigated by applying ANOVA. The experiments were planned basedon Taguchi's L_{27}orthogonal array. Results showed that surface roughness parameters (Ra and Rz) are mainly influenced by feed and cutting speed, whereas depth of cut exhibits minimum influence on surface roughness (Rz) and neglegible influence in case of surface roughness (Ra). The experimental data were further anlyzed to predict the optimal range of surface roughness parameters (Ra and Rz).

Keywords: Hard turning, AISI 4340 steel, Coated carbide inserts, Surface roughness, Taguchi design, ANOVA, Regression model.

Introduction

The achivement of high quality, in terms of workpiece dimensional accuracy, surface finish, high production rate, less wear on the cutting tools, economy of machining in terms of cost saving and increase the performance of the product with reduced enviornmental impact are the main and effective challenges of modern metal cutting and machining industries [1,2,3]. Traditionally, hardened steels are machined by grinding process due to their high strength and wear resistance properties but grinding operations are time consuming and limited to the range of geometries to be produced. This leads to reduced the number of setup changes, product cost and ideal time without compromising on surface quality to maintain the competiveness [4,5]. The improve technological process, proper tool selection, determination of optimum machining parameters (cutting speed, feed, depth of cut) or tool geometry (nose radius, rake angle, edge geometry, etc.) are necessary in order to obtain the desired surface finish comparable to grinding [6,7].

In order to decide the surface quality the statistical design of experiments (DOE) and

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statistical/mathematical model are used quite extensively. Statistical design of experiment refers to the process of planning the experimental so that the appropriate data can be analyzed by statistical methods, resulting in valid and objective conclusion [8]. Design and methods such as factorial design, Taguchi design and response surface methodology (RSM) are now widely used in place of one factor at a time experimental approach which is time consuming and exobitant in cost [9]. These methods have been used by some researchers for surface roughness [11], statistical method has been used for machinability [10].Davim and Figueira[10] to investigatethe machinability of cold work tool steel D2 heat treated to a hardnessof 60 HRC. They concluded that with an appropriate choice ofcutting parameters it is possible to obtain a surface roughness withRa < 0.8 µm. This implies that hard machining is an alternativecompetitive process, which allows eliminating cylindrical grindingoperation solutions. Sahin and Motorcu[11] developed the surface roughness model using responsesurface methodology in turning AISI 1050 hardened steelsby CBN cutting tools under different conditions. Feed ratewas found out to be the most significant factor on the surfaceroughness. Asiltürk and Akkus[12] carried out hard turning experiment on hardened AISI 4140 steel (51HRC) with coated carbide insert using Taguchi orthogonal array for surface roughness. Results of this study indicate that the feed rate has the most significant effect on Ra and Rz. In addition, the effects of two factor interactions of the feed rate-cutting speed and depth of cut-cutting speed appear to be important. A. Bhattacharya et al. [13] have investigated the effect of cutting parameters on surface finish and power consumption during high speed machining of AISI 1045 steel using Taguchi design and ANOVA. The result showed a significant effect of cutting speed on surface roughness and power consumption, while the other parameters have not substantially affected the response.

Motivation and objective of research work

Motivation of this project is to emphasis a deep review and a better scope on machining tools with the help of carbide tools.as per the papers revised and published easier the use of single layer carbide tool is optimized for determining R_a and R_z(surface roughness parameter) by on the basis of depth of cut, velocity and feed. In this work the multilayer carbide tool is used in spite of single layer carbide tool for better productivity and feasibility of withstand the smoothness of the surface and a comparing work is carried along to focus on the relative belt output which can further be optimized.The present study is to investigate the influence of machining parameters under the surface roughness in dry turning of hardened AISI 4340 steel with CVD ($TiN+TiCN+Al_2O_3+ZrCN$) multilayer coated carbide tool and determine the optimal levels of machining parameters for optimizing the surface roughness parameters (Ra and Rz) by employing Taguchi's orthogonal array design and utilizing analysis of variance (ANOVA). The relationship between the machining parameters (depth of cut, feed and cutting speed) and the performance measures i.e. surface roughness parameters (Ra and Rz) have been developed by using multiple second order regression models.

Development of tool materials

In all machining operations cutting speeds and feed are limited by the capability of the tool material. Speeds and feeds must be kept low enough to provide for an acceptable tool life. If not the time lost changing tools may outweigh the productivity gains from increased cutting speed. To maintain the above the cutting tool materials must have following properties:

- High hardness for easy penetration into the workpiece.
- High mechanical resistance to bending and compression so that it can withstand cutting forces.
- Resistance to abrasion, diffusion, spalling and plastic deformation.
- Resistance to high temperature which would otherwise diminish the qualities enumerated above.

No tool material can have all of those four properties. The uncoated cutting tool materials used in machining operation are: High carbon steel or Plain carbon steel, High speed steel (HSS), cemented carbide tools etc.

Fig. 1 HSS cutting tools

Parameterization A roughness value can either be calculated on a profile or on a surface. The profile roughness parameter (Ra, Rq,...) are more common. The areal roughness parameters (Sa, Sq...) give more significant values.The bars of 60mm in diameter and 100mm in length were heated to the proper austenitizing temperature of 9200C, holding at that temperature for 30 minute time to effect the desired change in crystalline structure and quenched in oil. After quenching, tempering was carried out i.e. the material is reheated to a predetermined temperature at about 4000C below the lower critical temperature range for two hours followed by air cooling to remove residual stresses in order to obtain a homogeneous structure. The hardness after heat treatment was obtained as 47±1HRC. The chemical compositions of AISI 4340 steel as received are given in Table 1.

Table 1 Chemical composition of AISI 4340 steel in percentage (%)

C	Mn	Cr	Mo	Ni	Si	Fe
0.39	0.77	1.1	0.17	1.55	0.38	Balance

1. EXPERIMENTAL PROCEDURE

The experiment has been conducted to analyze the effect of depth of cut, cutting speed and feed on surface roughness (Ra and Rz). The experiments were carried out with three parameters at three levels each, as shown in Table 2 and experiments were planned according to Taguchi's L_{27} (3^{13}) Orthogonal array with 26 degree of freedom. The turning experiments were carried out in order to obtain experimental data in the dry condition on CNC lathe machine (Jobber XL, AMS India) which has a maximum spindle speed of 3500 rpm and a maximum power of 16kW. Prior to actual machining, the skin layers were removed by a new cutting edge of uncoated carbide insert of very small depth of cut. This was done in order to remove the rust layer or hardened top layer from the outside surface and to minimize any effect of in homogeneity on the experimental results.

Table 2 Machining parameters and levels

Parameters	Unit	Levels		
		1	2	3
Depth of Cut (D)	Mm	0.3	0.4	0.5
Feed (F)	mm/rev	0.1	0.15	0.2
Cutting speed(V)	m/min	90	120	150

2. RESULTS AND DISCUSSIONS

The plan of the experiment has been developed for assessing the influence of the cutting speed (V), feed (F) and depth of cut (D) on the surface roughness parameters (Ra and Rz). Table illustrates the experimental results for surface roughness parameters. Minimal values of surface roughness criteria (Ra and Rz) were obtained at F = 0.1 mm/rev, V = 150 m/min and D = 0.4 mm (test number 12). Maximal values of surface roughness criteria (Ra and Rz) were registered at F = 0.2 mm/rev, V = 90 m/min and D = 0.4 mm (test number 16).

Table 3 Orthogonal array L_{27} of Taguchi experiment design and experimental results

Test No.	D	F	V	Ra(μm)	Rz(μm)
1	0.3	0.1	90	0.88	4.85
2	0.3	0.1	120	0.72	4.775
3	0.3	0.1	150	0.55	2.525
4	0.3	0.15	90	1.8	7.35
5	0.3	0.15	120	1.467	6.5
6	0.3	0.15	150	1.3	6.375
7	0.3	0.2	90	1.91	8.65
8	0.3	0.2	120	1.55	6.825
9	0.3	0.2	150	1.39	6.8
10	0.4	0.1	90	0.65	2.825
11	0.4	0.1	120	0.602	2.6
12	0.4	0.1	150	0.42	1.825
13	0.4	0.15	90	1.4	5.45
14	0.4	0.15	120	1.04	4.525
15	0.4	0.15	150	0.82	3.95
16	0.4	0.2	90	2.36	9.9
17	0.4	0.2	120	1.5	6.125
18	0.4	0.2	150	0.795	4.05
19	0.5	0.1	90	0.837	3.975
20	0.5	0.1	120	0.615	3.325
21	0.5	0.1	150	0.6	3.275
22	0.5	0.15	90	1.24	5.475
23	0.5	0.15	120	1.175	4.675
24	0.5	0.15	150	0.71	3.6
25	0.5	0.2	90	1.81	6.85
26	0.5	0.2	120	1.635	7.2
27	0.5	0.2	150	0.742	3.45

Analysis of variance (ANOVA) for SR

The experimental results are analyzed with analysis of variance (ANOVA), which is used for identifying the factors significantly affecting the performance measures. The results of the ANOVA with surface roughness Ra and Rz are shown in Tables 4 respectively. This analysis was carried out for significance level of α=0.05, i.e. for a confidence level of 95%.

Table 4 Analysis of variance for surface roughness (Ra)

Source	DOF	SS	MS	F-value	P	C (%)
D	2	0.32679	0.16340	4.81	0.043	4.91
F	2	3.49684	1.74842	51.45	0.000	52.55
V	2	1.72030	0.86015	25.31	0.000	25.85
D×F	4	0.21598	0.05400	1.59	0.267	3.24
F×V	4	0.48252	0.12063	3.55	0.060	7.25
D×V	4	0.13935	0.03484	1.03	0.450	2.10
Error	8	0.27186	0.03398			4.10
Total	26	6.65364				100
S = 0.184343	R-Sq = 95.91%	R-Sq(adj) = 86.72%				

The sources with a P-value less than 0.05 are considered to have a statistically significant contribution to the performance measures. The last column of the tables shows the percent contribution of significant source to the total variation and indicating the degree of influence on the result. The optimum setting obtained by graph as shown in fig. 2.

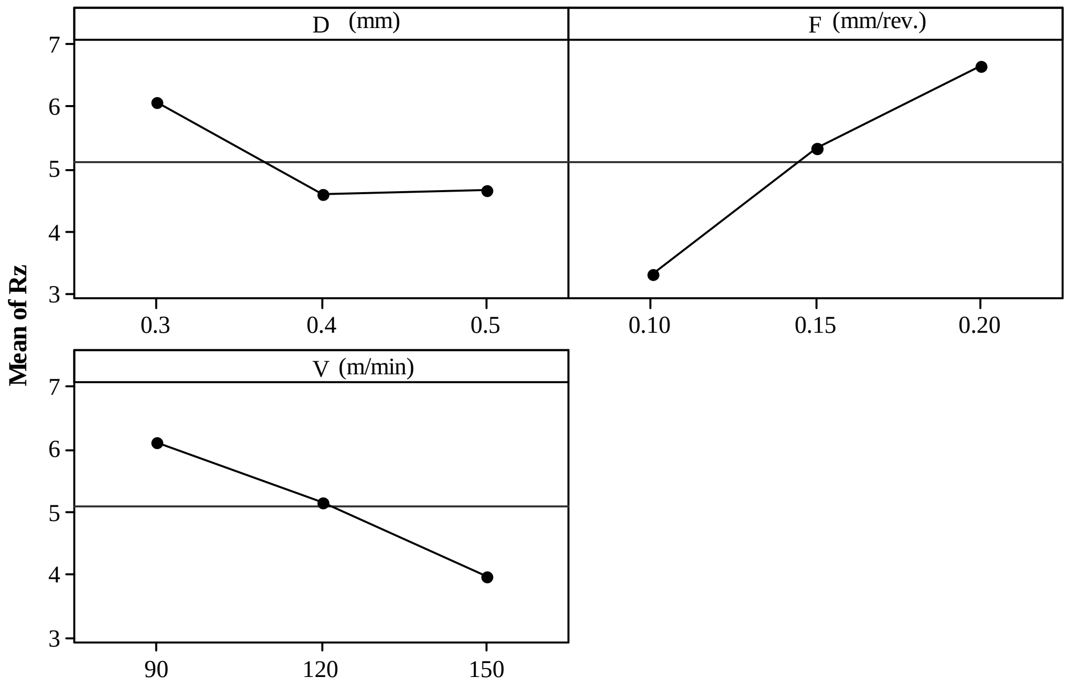

Fig. 2 Main effects plot for surface roughness (Rz)

3. Conclusions

The following conclusions are derived during turning of hardened AISI 4340 steel with CVD multilayer coated carbide insert. Also doing experimentation the effect of various machining parameters on surface roughness is studied.

1. Taguchi orthogonal array design have introduced to evaluate the effect of machining parameters on the surface roughness. Also the optimal machining conditions have been determined to minimize the surface roughness during turning operation.
2. The research finding along with the various mathematical analysis will provide the effective guidline to select machining parameters for achieving desired surface roughness during turning operation of hardened steel using coated carbide insert.

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