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Optimization of CNC Turning Parameters with Carbide Tool for Surface Roughness Analysis Using Taguchi Analysis

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Abstract

This experimental study concentrates on the understanding of machining process in turning of 11sMn30 using carbide tip insert under dry condition.11SMn30 is an alloy of magnesium and zinc which is mainly used for cutting steel and act as a very good rotating element in mechanical engineering and automobile components. The experiment was carried out using three input parameters namely cutting speed, feed rate and depth of cut. The main objective of the current work is to find out the optimal cutting conditions that affect the surface roughness values Ra and Rz. Tool used for the study was Taguchi analysis. The optimum values for surface roughness Ra and Rz is found to be 1.854 and 12.899 respectively. Also it was found out that the feed rate is the most significant factor on the surface roughness of the work piece.

Keywords: Turning, optimization, Taguchi analysis.

Introduction

A large number of engineering components, such as shafts gears bearing, clutches, cams, screw-nuts, etc need reasonably high dimensional and form accuracy and good surface finish for serving their functional purposes. Performing the casting forging, rolling etc generally cannot provide the desired accuracy and finish. For that, performed objects called blanks need semi finishing and finishing and this is done by machining and grinding. Therefore briefly stated that the engineering components are essentially finished to accuracy and surface finish by machining to enable the product. Machining is an essential finishing process by which jobs of desired dimensions and surface finish are produced by gradually removing the excess material from the performed blank in the form of chips with the help of cutting tools moved past the work surfaces. Surface roughness defines the conditions of a machined surface. The most important factor in determining the character of a surface is surface roughness. The main reasons for surface irregularities are issues that are concerned with machining operations. The magnitude of surface irregularities can range according to the impact of both internal and external factors that affects machining. These irregularities will finally result in performance of the final product in terms of durability, operating noise, air tightness and friction. Errors in machining can also affect the shining appearance if it the product demands that property.

Rodrigues, Kantharaj and Freitas presented a method to determine the effect of the cutting parameters on surface roughness and cutting force in turning mild steel[1]. Experiments were carried out using full factorial design and the tool used for this study was ANOVA. As a result of the study conducted, it was found out that the influencing factor was feed rate followed by cutting speed and depth of cut.

Kagde and Deshmukh made an attempt to find out the effect of cutting parameters on multiple performance characteristics (work piece surface roughness, spindle load) obtained by turning operations. CNMG 090308 PF carbide insert as tool and HCHC steel as work piece material were used in experiments[2]. Results showed that Spindle Speed and Feed rate were the more critical attributes on multiple cutting performance characteristics. The main tool used for the study was Experimental analysis. At high speeds, surface finish is least affected. At low speed surface roughness increases with increasing optimum values of HCHC work piece material were speed 1700 rmp, feed rate 0.1rev/min and depth of cut 0.05 to 0.1 mm.

Rajmohan, Palanikumar and Kathirvel used the combination of Taguchi method and grey relational analysis to optimize the machining parameters in drilling hybrid metal matrix Al356/SiC-mica composites[3]. The input parameters were feed rate, spindle speed, drill type and mass fraction of mica. The output parameters were tool wear, burr height trust force and surface roughness. From the results, it was found out that the most significant factors that affect drilling were feed rate and the type of drill.

Azlan, Haron and Safian made an attempt to search for a set of optimal process parameter value that leads to minimize the value of machining performance[4]. This study aimed at optimizing machining performance and the input parameters. The Input parameters considered for the study were traverse speed, water jet pressure, standoff distance, grit size and flow rate. The main tools were using Genetic Algorithm and Simulated Annealing. The result of this study explains that genetic algorithm and simulated annealing were best in the case of finding the optimal process parameters.

Murthy and Lewlyn made an attempt to analyze and optimize the Surface Roughness in Drilling GFRP[5]. The main tools used were Taguchi analysis and Response Surface Methodology. The input parameters selected were feed rate, spindle feed, drill diameter and point angle. The drilling tool used for the experiment was solid carbide drill bit. The study concluded that except the spindle speed, all the other input parameters increase the surface roughness value with the increase in corresponding value.

Bharat, Saumya, Saurav, Asish and Siba conducted a study on multi-objective optimization[6]. The material used was UNS C34000 medium leaded brass. The machining was done using CNC machining center and the analysis was made using Taguchi method. This study also made use of S/N ratio. The main conclusion of this study depicts that the utility based Taguchi approach was effective in evaluating the optimal performance setting.

Krishna and Bharathi suggested an approach for finding the best cutting parameters leading to minimum surface roughness and maximum Material Removal Rate[7]. The material used was Cast Iron and the experiment was done on a machining Centre. Experimental attributes were obtained from MATLAB. The researcher used genetic algorithm coupled with artificial neural network which leads to find out the minimum value of Ra and Rz.

Tao, Jibin and Weijun made an investigation on the optimization of high speed machining of NAK 80 mild steel[8]. Tools used for this study were the combination of Grey relational analysis and Taguchi analysis. Cutting speed, feed rate and depth of cut were used to find out the response. It was found out that the depth of cut was the most influential factor and the optimized cutting parameters were feed rate 0.10 mm/rev, depth of cut 0.20 mm and cutting speed 2400 r/min.

Saikumar and Shunmugam conducted a study on high speed machining with rough and finish end-milling. The material used was hardened EN24 steel[9]. The tools used for the study are Design of experiment (DOE) and artificial neural network (ANN). The result of the study concludes the effectiveness of ANN and DOE in optimizing high-speed end-milling to attain high quality product and production.

Mangesh, Tatwawadi and Modak presented a model and simulation of productivity in turning of Ferrous and Nonferrous material using artificial neural network and response surface methodology[10]. Also a mathematical model was formed to increase productivity. Machining time and machining cost are the important factors for increasing the productivity.

Gaitondea, Karnikb and Paulo presented a method for simultaneously minimizing the delamination factor at entry and exit of the drilled holes in drilling of SUPERPAN D´ECOR (melamine coating layer) MDF panel[11]. The tool used was Taguchi analysis, Analysis of means and Analysis of variance. L9 orthogonal array were used for the experiment and each experiment was conducted at different conditions of cutting sped and feed rate. The findings showed that the delaminating can be effectively reduced in the case of drilling MDF materials by employing high cutting speed and low feed rate.

Tosun utilized taguchi analysis and signal to noise ratio to study the statistical analysis of process parameters in minimizing the surface roughness[12]. The material used was Al/SiCp metal matrix composite. Spindle speed, drill type, point angle of drill and heat treatment were selected as the input parameters. The main tool used for analysis was ANOVA which was used to find the level of importance. The conclusions made was the optimal surface roughness was obtained at 130° drill point angle, 260 rev/min spindle speed, 0.16 mm/rev feed rate and carbide drill type.

Ramesh, Karunamoorthy and Palanikumar conducted a study on the effect of cutting parameters on the surface roughness in turning operations[13]. The material used was an alloy of titanium; tool used is RCMT 10T300 –MT TT3500 round insert, and tool used was response surface methodology .The input parameters were cutting speed, feed and depth of cut. The chip formation and Scanned Electron Microscopic images were studied. The results showed that Surface roughness was affected by feed rate.

Nagaraja, Mervin, Divakara, Raviraj and Shivamurthy studied the effects of process parameters and delamination factor[14]. The input factors were spindle speed and feed rate, the output parameters are delamination factor, thrust force and torque. It was observed that the feed rate made the largest contribution to delamination, thrust force and torque.

Palanikumar and Davim studied the prediction of tool wear on the machining of GFRP composites using regression and ANOVA. They studied the main effect and interaction effect of the input machining parameters, viz cutting speed, feed rate, depth of cut and fiber orientation of the work piece[15]. From the study conducted it was found out that the cutting speed was the most significant factor that affects the tool wear followed by feed rate.

Palanikumar, Karunamoorthy and Karthikeyan studied the influence of machining parameters on the machining of GFRP composites[16]. Design of experiments was used as a tool for doing the experiments. The machining experiments were

conducted on geared lathe and the tool used was coated cement tool inserts with two levels of factors. The input parameters selected for the study were depth of cut, feed rate, cutting speed, work piece fiber orientation angle. From the study conducted it was seen that feed rate is the most significant factor which has greater influence on surface roughness, followed by cutting speed and depth of cut.
In the current study CNC turning is carried out on 11sMn30 and WIDIA CNMG 120408-49-TN 2000 was used as tool tip using various important machining parameters namely cutting speed, feed rate and depth of cut. Surface roughness was measured using Mitutoyo SJ-210 portable surface roughness testing machine and reading were recorded and analyzed. The data obtained from the experiment was analyzed using Taguchi's analysis to find out the optimum combination of machining parameters in terms of depth of cut, cutting speed and feed rate.

Figure-1
Mitutoyo SJ-210 portable surface roughness tester

Methodology

The experiment is planned according to Taguchi's L_9 orthogonal array. The three input parameters has three levels, hence L_9 orthogonal array is selected for the experiment. The experiment work was carried out on CNC Turning Center STALLION 200, the main drive power is 7.5KW and the speed range was in the range 100-4000rpm. Work material was an alloy of mild steel and magnesium rod (22Ǿ x 150mm), 11SMn30 was used for the experiment. Its composition is 0.08%C, 0.04%Si, 1.10%Mn, 0.07%P, 0.30%S. Tensile Strength of the material is 395N/mm^2 and hardness of 159HB. 11SMn30 is an alloy of magnesium and zinc which is mainly used for cutting steel and act as a very good rotating element in mechanical engineering and automobile components. WIDIA CNMG 120408-49-TN 2000 was used as tool tip. Three input parameters selected for the experiment are spindle speed, Feed rate and depth of cut and details are given below in table 1.

Table-1

Symbol	**Control Factor**	**Unit**	**Level 1**	**Level 2**	**Level 3**
V	Cutting speed	m/min	135	180	225
f	Feed rate	mm/rev	0.1	0.2	0.3
d	Depth of Cut	mm	0.5	1	1.5

The surface roughness Ra and Rz, were measured using Mitutoyo SJ-210 portable surface roughness tester. These values were the average of four values measured from the three different points on the circumference of the machined part.

Figure-2
CNC Turning Center STALLION 200

Results and Discussion

The surface roughness Ra and Rz were measured using the input factors namely cutting speed, feed rate and depth of cut. The response, surface roughness was measured by varying the machining parameters and the corresponding values is shown in table 2. The statistical analysis is done using MINITAB (version17) software for obtaining the main effect, interaction effect and graphs. The surface roughness plots for signal to noise ratios and means are given in table 3 and 4.

Table-2
Experimental results

SL NO	Control factor levels			Surface Roughness	
	Cutting Speed V(m/min)	Feed Rate f(mm/rev)	Depth of cut d(mm)	Ra(µm)	Rz(µm)
1	135	0.1	0.5	2.752	19.3144
2	135	0.2	0.5	2.987	21.0564
3	135	0.3	0.5	3.356	23.759
4	135	0.1	1	2.556	17.976
5	135	0.2	1	2.745	19.264
6	135	0.3	1	2.907	20.4304
7	135	0.1	1.5	2.351	17.001
8	135	0.2	1.5	2.618	18.3496
9	135	0.3	1.5	2.945	20.704
10	180	0.1	0.5	2.805	19.769
11	180	0.2	0.5	3.145	22.144
12	180	0.3	0.5	3.256	22.94
13	180	0.1	1	2.409	16.844
14	180	0.2	1	2.789	19.5808
15	180	0.3	1	2.9997	21.197
16	180	0.1	1.5	2.456	17.1832
17	180	0.2	1.5	2.554	17.869
18	180	0.3	1.5	2.921	20.956
19	225	0.1	0.5	2.558	17.152
20	225	0.2	0.5	2.7005	18.964
21	225	0.3	0.5	2.981	19.97
22	225	0.1	1	1.955	13.597
23	225	0.2	1	2.252	15.794
24	225	0.3	1	2.455	17.176
25	225	0.1	1.5	1.854	12.899
26	225	0.2	1.5	2.177	15.1744
27	225	0.3	1.5	2.426	17.01

Table-3
Response table for means (Smaller is better)

Level	Cutting Speed	Feed rate	Depth of cut
1	2.802	20411	2.949
2	2.815	2.663	2.563
3	2.373	2.916	2.478
Delta	0.442	0.506	0.471
Rank	3	1	2

Table-4
Response table for noise ratios (Smaller is better)

Level	Cutting Speed	Feed Rate	Depth of cut
1	-8.908	-7.568	-9.361
2	-8.946	-8.453	-8.106
3	-7.419	-9.251	-7.805
Delta	1.527	1.683	1.557
Rank	3	1	2

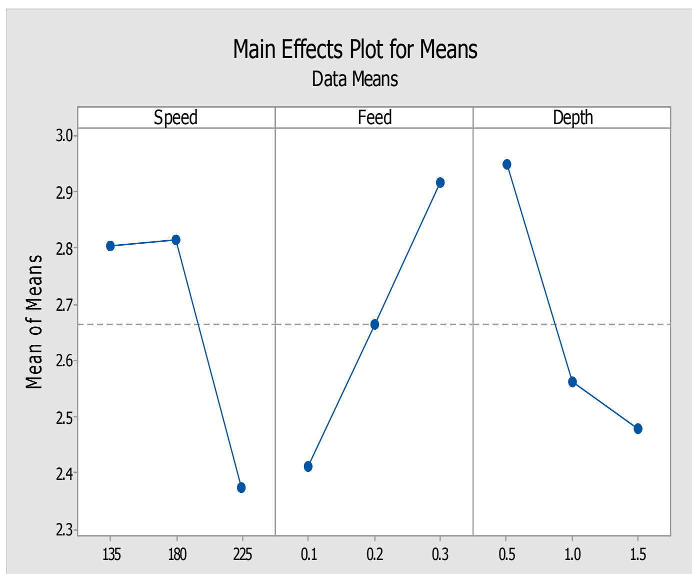

Figure-3
Main effects plot for means(Ra)

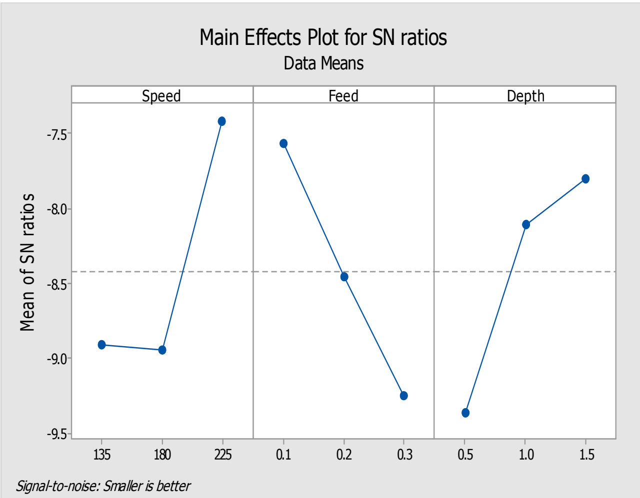

Figure-4
Main effects plot for SN ratio(Ra)

Figure-5
Interaction plots for Means (Ra)

Figure-6
Interaction plots for SN ratios Means (Ra)

Graphs are drawn from the data obtained from the experiments. As shown in figure 3, when Speed increases surface roughness also increases. But when feed increases surface roughness decreases. But in the case of depth of cut, it increases with increase in surface roughness values. In the case of SN ratios, surface roughness increases with increase in cutting speed. But when Feed rate decreases, the surface roughness value also decreases. Whereas in the case of depth of cut the surface roughness value increases with increase in depth of cut. Interaction plots for means and SN ratios are shown in figure 5 and 6 respectively. From the Taguchi analysis it was found that the feed rate is the most important significant factor which affects the surface roughness Ra followed by cutting speed and depth of cut respectively.

Table-5
Response table for means Rz (Smaller is better)

Level	Cutting Speed	Feed Rate	Depth of Cut
1	19.76	16.86	20.56
2	19.83	18.69	17.98
3	16.42	20.46	17.46
Delta	3.42	3.6	3.1
Rank	2	1	3

Table-6
Response table for Signal to noise ratios, Rz (Smaller is better)

Level	Cutting Speed	Feed Rate	Depth of Cut
1	-25.88	-24.46	-26.22
2	-25.9	-25.37	-25.02
3	-24.23	-26.17	-24.76
Delta	1.67	1.71	1.46
Rank	2	1	3

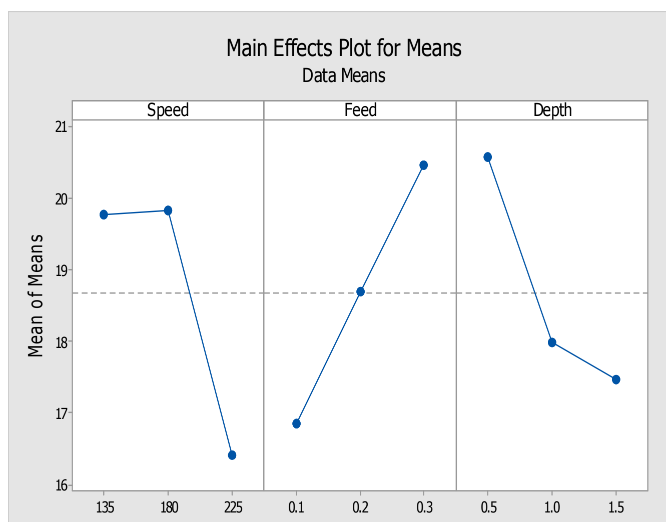

Figure-7
Main effects plot for means(Rz)

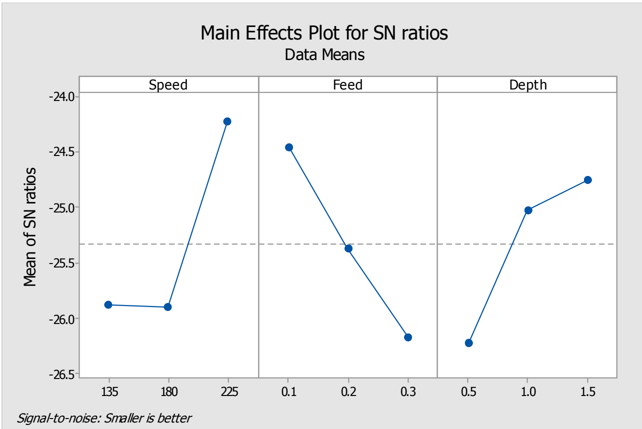

Figure-8
Main effects plot for SN ratio (Rz)

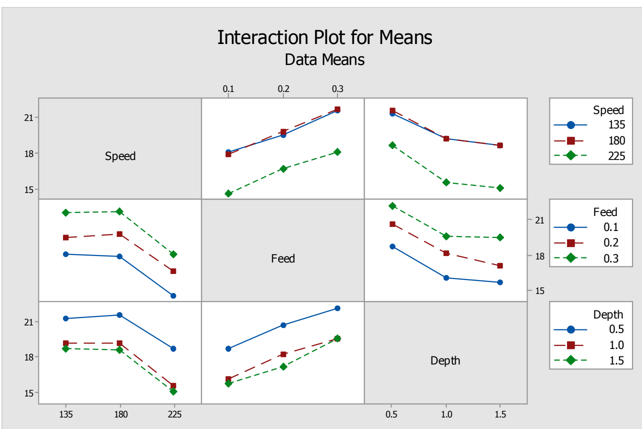

Figure-9
Interaction plots for Means (Rz)

Figure-10
Interaction plot for SN ratio (Rz)

Graphs are drawn from the data obtained from the experiments. As shown in figure 7, when Speed increases surface roughness also increases. But when feed increases surface roughness decreases. But in the case of depth of cut, it increases with increase in surface roughness values. In the case of SN ratios, surface roughness increases with increase in cutting speed. But when Feed rate decreases, the surface roughness value also decreases. Whereas in the case of depth of cut the surface roughness value increases with increase in depth of cut. Interaction plots for means and SN ratios are shown in figure 9 and 10 respectively. From the Taguchi analysis it was found that the feed rate is the most important significant factor which affects the surface roughness Rz followed by cutting speed and depth of cut respectively.

Conclusion

The present work shows the use of Taguchi method to find out optimal machining parameter. The S/N ratio for the test results were found out using the Taguchi method. Machining Parameters namely cutting speed (V), Feed rate (f), depth of cut (d) is optimized to meet the objectives. As a result of the study the following conclusions are drawn: i. The results reveal that the primary factor affecting the surface roughness is feed rate, subsequently followed by speed and depth of cut. ii. The optimized factor for minimizing the Surface roughness Ra is Feed rate f_1=0.1mm/rev, Cutting speed, V_3=225m/min, Depth of Cut d_3=1.5mm. ii.The optimized factors for minimum Surface roughness Rz is Feed rate f_1=0.1mm/rev, Cutting speed, V_3=225m/min, Depth of Cut d_3=1.5mm. iii. From the Taguchi analysis it was found that the feed rate is the most important significant factor which affects the surface roughness Ra and Rz followed by cutting speed and depth of cut respectively.

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