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Optimization of Turning Parameters with Carbide Tool for Surface Roughness 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 in the free cutting steel for bulk applications for joining elements in mechanical engineering and automotive components. The experimentation was carried out using three variables namely cutting speed, feed rate and depth of cut. The main objective of this work is to find out the optimal cutting parameters that affect the surface roughness values Ra and Rz. Tool used for the study was Taguchi analysis. The optimized values for surface roughness Ra and Rz were obtained and found out that the effect of feed rate is the most significant factor on the surface roughness of the work piece.*

Keywords: *Turning, Optimization, Taguchi analysis*

1. 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 indicates the state of a machined surface. Surface roughness plays an important role in defining the character of a surface. The surface irregularities of a component or material may be intentionally created by machining, but they can also be created by a wide range of factors such as tool wobbling caused by motor vibration during machining, the quality of the tool edge and the nature of the machined material. The form and size of irregularities vary, and are superimposed in multiple layers, so differences in those irregularities impact the quality and functions of the surface. The results of these irregularities can control the performance of the end product in aspects such as friction, durability, operating noise, energy consumption, and air tightness. If the products in question are printing paper or exterior panels, aspects of quality such as glossiness and adhesion of paint and ink can also be affected by surface roughness. The shape and size of irregularities on a machined surface have a major impact on the quality and performance of that surface, and on the performance of the end product. The quantification and management of fine irregularities on the surface, which is to say, measurement of surface roughness, is necessary to maintain high product performance. Some of the related literature studies are given below: Kagde and Deshmukh investigated on the optimization and 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 [1]. 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. T. Rajmohan, K. Palanikumar and M. Kathirvel used Taguchi method and grey analysis to optimize the machining parameters in drilling hybrid metal matrix Al356/SiC-mica composites [2]. The drilling parameters were spindle speed, feed, drill type and mass fraction of mica were optimized based on the multiple performance characteristics including trust force, surface roughness, tool wear and burr height .the results obtained depicts that the feed rate and the type of drill are the most significant factors which affect the drilling process. Azlan Mohd Zain, Habibollah Haron and Safian Sharif made an attempt using Genetic Algorithm and Simulated Annealing to search for a set of optimal process parameters value that leads to the minimum value of machining performance [3]. The main objectives included estimatimation of machining performance, estimation of the optimal process parameters values that has to be within the range of the minimum and maximum coded values for process parameters of experimental design and to evaluate the number of iteration generated by the computational approaches that lead to the minimum value of machining performance. The results of this study showed that both of the computational approaches managed to estimate the optimal process parameters, leading to the minimum value of machining performance when compared to the result of real experimental data.

Bharat Chandra Routara,Saumya Darsan Mohanty, Saurav Datta,Asish Bandyopadhyay And Siba Sankar Mahapatra conducted a study on a multi-objective optimization problem by applying utility concept coupled with Taguchi method through a case study in CNC end milling of UNS C34000 medium leaded brass. This study also made use of S/N ratio [4]. The case study indicates application feasibility of the aforesaid methodology proposed for multiresponse optimization and off-line control of multiple surface quality characteristics in CNC end milling. Tao FU, Jibin ZHAO and Weijun LIU made an investigation on the optimization problems of cutting parameters in high speed milling of NAK 80 mold steel [5]. Tools used were Grey relational analysis and taguchi analysis and the input parameters were cutting speed, feed and depth of cut. The results of experiments show that grey relational analysis coupled with principal component analysis can effectively acquire the optimal combination of cutting parameters and the proposed approach can be a useful tool to reduce the cutting force.

S. Saikumar & M. S. Shunmugam conducted a study on Investigations into high-speed rough and finish end-milling of hardened EN24 steel for implementation of control strategies [6]. EN24 steel using single Insert cutter under different sets of cutting parameters for roughing and finishing operations. A response surface is developed to predict material removal volume and a set of cutting parameters is selected for a given range of material removal volume using differential evolution (DE) algorithm till the tool wear reaches certain value. The experimental data is also used to develop Bayesian-based artificial neural network (ANN) model. The predicted responses of ANN models will be useful to develop real-time control strategy for high-speed end-milling to achieve high productivity and quality.

V.N. Gaitondea, S.R. Karnikb and J. Paulo Davimc presented a methodology of Taguchi optimization method for simultaneous minimization of delimitation factor at entry and exit of the holes in drilling of SUPERPAN D´ECOR (melamine coating layer) MDF panel [7] . The experiments were carried out as per L9 orthogonal array with each experiment performed under different conditions of feed rate and cutting speed. The analysis of means (ANOM) was performed to determine the optimal levels of the parameters and the analysis of variance (ANOVA) was employed to identify the level of importance of the machining parameters on delimitation factor. The investigations revealed that the delaminating can be effectively reduced in drilling of MDF materials by employing the higher cutting speed and lower feed rate values.

Gül Tosun utilized taguchi analysis and signal to noise ratio to perform the statistical analysis of process parameters for surface roughness in drilling of Al/SiCp metal matrix composite [8]. The input parameters were spindle speed, feed rate, drill type, point angle of drill, and heat treatment. The level of importance of the drilling parameters is determined by using analysis of variance. The optimal drilling performance for the surface roughness was obtained at 0.16 mm/rev feed rate, 260 rev/min spindle speed, 130° drill point angle, carbide drill type, and as-received heat treatment settings.

S. Ramesh ,L. Karunamoorthy and K. Palanikumar conducted a study on the effect of cutting parameters on the surface roughness in turning of titanium alloy has been investigated using response surface methodology .the input parameters were cutting speed, feed and depth of cut [9]. The chip formation and SEM analysis are discussed to enhance the supportive surface quality achieved in turning. The work material used for the present investigation is commercial aerospace titanium alloy (gr5) and the tool used is RCMT 10T300 –MT TT3500 round insert. The equation developed using response surface methodology is used for predicting the surface roughness in machining of titanium alloy. The results revealed that the feed was the most influential factor which affects the surface roughness. K. Palanikumar and J. Paulo Davim developed a mathematical model has been developed to predict the tool wear on the machining of GFRP composites using regression analysis and analysis of variance (ANOVA) in order to study the main and interaction effects of machining parameters, viz., cutting speed, feed rate, depth of cut and work piece fiber orientation angle [10].From the study conducted it was found out that the cutting speed has the most significant effect on tool wear followed by feed rate . K. Palanikumar, L. Karunamoorthy and R. Karthikeyan made an attempt to assess the influence of machining parameters on the machining of GFRP composites [11]. Design of experiments was used as a tool for doing the experiments. The machining experiments were conducted on all geared lathe using coated cement tool inserts with two levels of factors. The factors considered were cutting speed, work piece fiber orientation angle, depth of cut and feed rate. From the study conducted it was noted that feed rate is the factor, which has greater influence on surface roughness, followed by cutting speed.

In this study the turning was 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 tester after machining was completed .The data obtained from the experiment was analyzed using Taguchi’s analysis to determine the combination of machining parameters that offer the best optimal performance in terms of cutting speed, feed and depth of cut .

2. EXPERIMENTAL PROCEDURE

The experiments were planned by making use of Taguchi’s orthogonal array (Design of Experiments) and conducted using a 3 level L_9 orthogonal array. 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.Mainly Applied in the free cutting steel for bulk applications for joining elements in mechanical engineering and automotive components. WIDIA CNMG 120408-49-TN 2000 was used as tool tip. The literature survey and in agreement with ISO 3685 identified the turning parameters and their levels for the experiment. As a result three parameters such as spindle speed, Feed rate and depth of cut are selected and experimental conditions are given in the table below

Table1. *Cutting parameters and their levels for turning*

Symbol	Control Factor	Unit	Level 1	Level 2	Level 3
V	speed	m/min	135	180	225
f	Feed	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.

Fig1. *Mitutoyo SJ-210 portable surface roughness tester*

Fig2. *CNC Turning Center STALLION 200*

3. RESULTS AND DISCUSSIONS

The surface roughness parameters were measured using the input factors namely cutting speed, feed rate and depth of cut. The measured response surface roughness corresponding to the

Table2. *Experiment results and their S/N ratios*

	Control factors			Surface roughness	
Sl no	Speed	Feed	Depth of cut	Ra	Rz
	m/min	mm/rev	mm	µm	µm
1	135	0.1	0.5	3.512	-10.911
2	135	0.2	1	2.647	-8.4551
3	135	0.3	1.5	2.65	-8.4649
4	180	0.1	1	2.409	-7.6367
5	180	0.2	1.5	2.38	-7.5315
6	180	0.3	0.5	3.984	-12.006
7	225	0.1	1.5	1.897	-5.5613
8	225	0.2	0.5	2.878	-9.1818
9	225	0.3	1	2.348	-7.414

Varying machine parameters is shown in table 2. The main statistical analysis was done with the help of MINITAB software for obtaining the main effects. The main effect of a factor may be described as the average change in the response generated by a change in the level of a factor studied. Suppose if the line is horizontal in the main effects plot, it is that there is no main effect. The magnitude of main effect depends upon the difference in the vertical position of the plotted points. When the vertical position of plotted points is found to be with a larger distance, the magnitude of the main effect also would have a much difference. The surface roughness plots for signal to noise ratio and means are given below.

Table3. *Response table for Signal to noise ratios for Ra (Smaller is better)*

level	Speed	Feed	Depth
1	-9.277	-8.036	-10.7
2	-9.058	-8.389	-7.835
3	-7.386	-9.295	-7.186
Delta	1.891	1.259	3.514
Rank	**2**	**3**	**1**

Table4. *Response table for Means (Smaller is better)*

Level	Speed	Feed	Depth
1	2.963	2.606	3.458
2	2.924	2.636	2.468
3	2.374	2.994	2.309
Delta	0.562	0.388	1.149
Rank	**2**	**3**	**1**

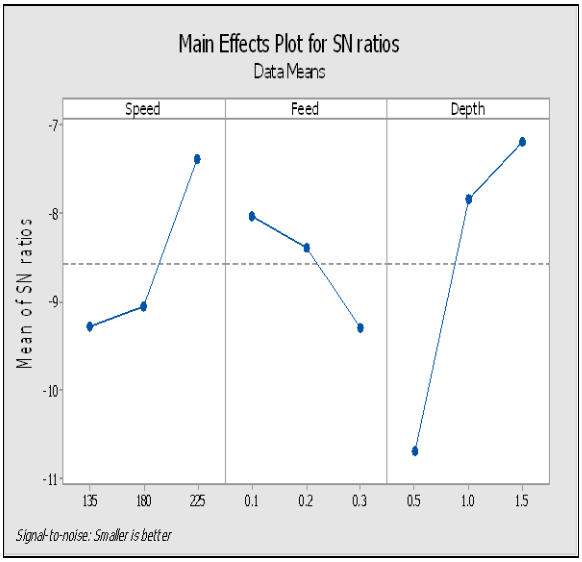

Fig3. *Main effects plot for SN ratio(Ra)*

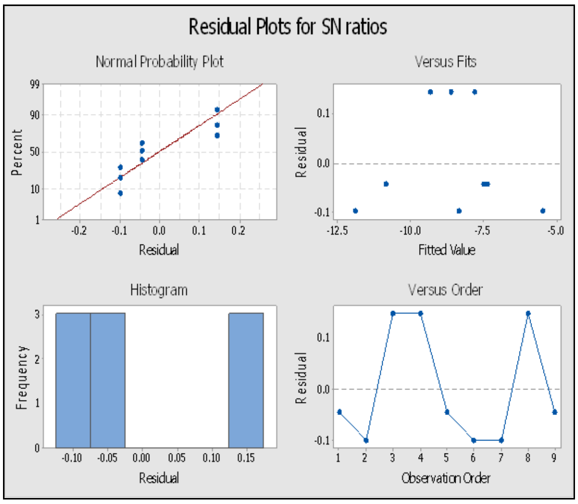

Fig4. *Residual plots for SN ratio (Ra)*

3.1. Effect of Speed, feed and depth of cut on surface roughness Ra

Graphs are drawn from the data obtained from the experiments. It is observed that surface roughness Ra is constant at speed 135m/min and 180m/min but decreases towards speed 225m/min.Initially surface roughness Ra is minimum against minimum feed rate . But as feed increases surface roughness also increases.

Table5. *Response table for Signal to noise ratios for Rz (Smaller is better)*

level	Speed	Feed	Depth
1	-26.46	-25.14	-27.77
2	-26.34	-25.59	-25.02
3	-24.39	-26.45	-24.38
delta	2.07	1.31	3.39
rank	2	3	1

Table6. *Response table for Signal to noise ratios for Rz (Smaller is better)*

level	Speed	Feed	Depth
1	21.19	18.7	24.68
2	24.29	19.07	17.86
3	16.84	21.56	16.79
delta	4.45	2.87	7.89
rank	2	3	1

In the case of depth of cut, Surface roughness is maximum at 0.5mm/rev but decreases as depth of cut increases to 1.5/mm/rev. In the case of SN ratios, surface roughness Ra is minimum at lower speed and it gradually increases with increase in speed. But in the case of lower feed rate, surface roughness Ra is maximum and as feed increases, Ra decreases. At lower depth of cut, surface roughness is less. As depth of cut increases, Surface roughness also increases. As a result of Taguchi analysis it was found that depth of cut has the maximum effect on surface roughness Ra followed by speed and feed respectively.

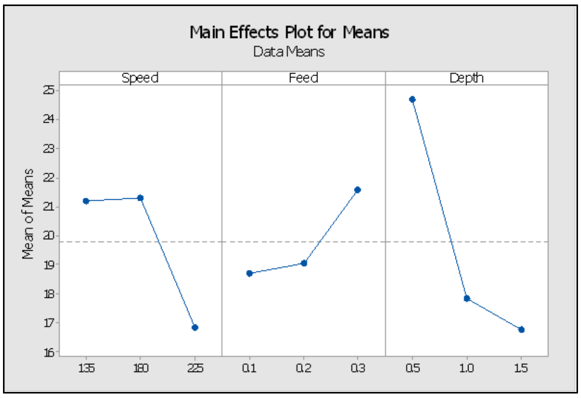

Fig5. *Main effects plot for means(Rz)*

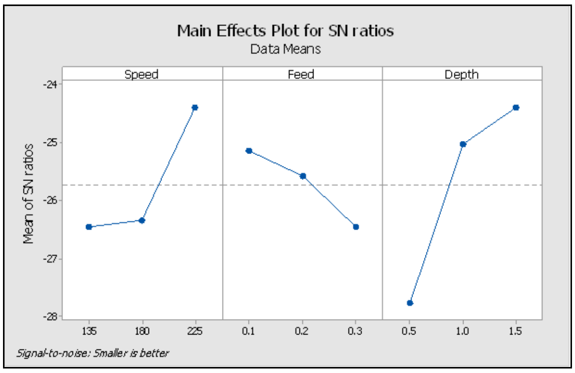

Fig6. *Main effects plot for SN ratio (Rz)*

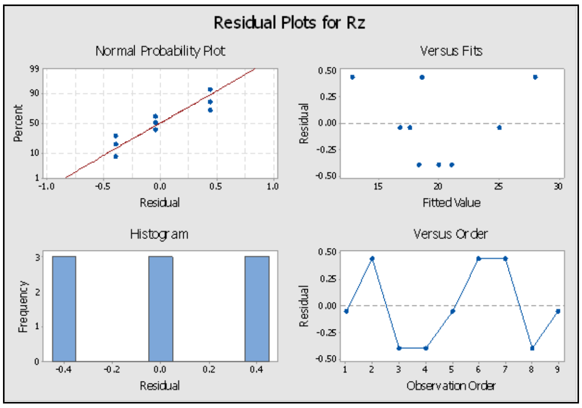

Fig7. *Residual plots for SN ratio (Ra)*

3.2. Effect of Speed, feed and depth of cut on surface roughness Rz

Graphs are drawn from the data obtained from the experiments. It is observed that surface roughness Rz is constant at speed 135m/min and 180m/min but decreases towards speed 225m/min. Initially surface roughness Rz is minimum with minimum feed rate. But as feed increases surface roughness also increases. In the case of depth of cut, Surface roughness is maximum at 0.5mm/rev but decreases as depth of cut increases to 1.5/mm/rev. In the case of SN ratios, surface roughness Rz is minimum at lower speed and it gradually increases with increase in speed. But in the case of lower feed rate, surface roughness Rz is maximum and as feed increases, Rz decreases. At lower depth of cut, surface roughness is less. As depth of cut increases, Surface roughness also increases. As a result of Taguchi analysis it was found that depth of cut has the maximum effect on surface roughness Ra followed by speed and feed respectively.

4. CONCLUSION

The present work shows the use of Taguchi method to find out optimal machining parameter. By using the Taguchi method we determine the S/N ratio for all the experimental tests. Machining Parameters namely Cutting speed V, Feed rate f, depth of cut d were optimized to meet the objective .As a result of the study the following conclusions are drawn:

- The observation result shows that the primary factor affecting the surface roughness is depth of cut, subsequently followed by cutting speed and feed.
- The optimized control factors for minimizing the Surface roughness Ra were Cutting speed, V_3=225m/min, Feed rate f_1=0.1mm/rev, Depth of Cut d_3=1.5mm
- The optimized control factors for minimum Surface roughness Rz were Cutting speed, V_3=225m/min, Feed rate f_1=0.1mm/rev, Depth of Cut d_3=1.5mm
- From the Taguchi's analysis it was found that the depth of cut is the most dominant factor affecting the surface roughness, Ra and Rz.

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