OPTIMIZATION OF SURFACE ROUGHNESS USING TAGUCHI METHOD IN END MILLING OF STEEL GRADE EN19 WITH TIN COATED CARBIDE TOOL

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Abstract— In this paper, the Taguchi method has been applied to optimize the machining performance in terms of surface quality of the product, with EN 19 grade steel of cross section 100mm×100mm×20mm as the work piece. Tin-coated carbide cutting tool having four flute 8mm diameter, shank length 30mm and cutter length 35mm is used for experiment on a vertical milling machine SV-2E. Taguchi's L9 orthogonal array is employed for the experimentation. The factors considered for experimentation and analysis were cutting speed, feed rate and depth of cut. Signal-to-noise (S/N) ratio and analysis of variance (ANOVA) were employed to analyze the effect of these milling parameters. The analysis results revealed that the spindle speed was the dominant factor affecting surface roughness. Confirmation test results showed that the Taguchi method was very successful in the optimization of machining parameters for minimum surface roughness.

Keywords— Analysis of variance (ANOVA), milling, surface roughness, Taguchi method

I. INTRODUCTION

The machining industries are facing a great challenge to achieve high quality, good surface finish and high material removal rate with a view to economize in machining. End Milling is widely used in a variety of manufacturing industries including the aerospace and automotive sectors, where quality is an important factor in the production of slots, pockets, precision molds, and dies because good-quality milled surface significantly improves fatigue strength, corrosion resistance, and creep life. The setting of machining parameters relies strongly on the experience of operators and machining parameter tables provided by machine tool builders. It is difficult to utilize the optimal functions of a machine owing to there being too many adjustable machining parameters. Surface roughness is an important measure of the technological quality of a product and a factor that greatly influences manufacturing cost. The mechanism behind the formation of surface roughness is very dynamic, complicated and process dependent so its calculation through theoretical analysis is difficult. Therefore, machine operators usually use "trial and error" approaches to set-up milling machine cutting conditions in order to achieve the desired surface roughness which is not effective and efficient and the achievement of a desirable value is a repetitive and empirical process that can be very time consuming. The dynamic nature and widespread usage of milling operations in practice have raised a need for seeking a systematic approach that can help to set-up milling operations in a timely manner and also to help achieve the desired surface roughness quality. The goal of the modern industries is to manufacture low cost, high quality product in short time. In milling to achieve high cutting performance, selection of optimum parameter selection is determined by the operator's experience knowledge or the design data book. But the availability of valid experimental data is very limited for machining with advanced cutting tool. The machinability of hardened steel was evaluated by measurement of tool wear, cutting force and surface finish of work piece. Design methods such as factorial design, response surface methodology (RSM) and Taguchi methods are now widely used in place of one factor at a time experimental approach. Taguchi method is one of the Design of Experiment (DOE) methods that are frequently being used for optimization due to saving of cost, time and material. The Taguchi's dynamic experiments are simple, systematic and efficient method to determine optimum or near optimum settings of machining parameters. It optimizes the performance characteristic through the setting design parameter and reduces the sensitivity of the system performance due to variation of source. In this study we use Taguchi method to find optimal process variable to achieve minimum variation from targeted value in the milling of EN 19 material by Tin-coated carbide tool. Analysis of variance (ANOVA) was used as the analytical tool in studying effects of these machining variables. Assumptions of ANOVA were discussed and carefully examined using analysis of residuals.

II. EXPERIMENTAL METHOD

The experiment of end milling is carried out on a vertical milling machine SV-2E equipped with maximum spindle speed of 1500 rpm, maximum feed 800mm/minute. The work material used was steel grade EN19 in the form of a 100mm×100mm×20mm block. The machining parameters which vigorously affect the surface roughness are identified based on experience, discussion made with the expert, survey of literature, the parameters and their chosen levels are shown in table 1. The experiment was conducted using Tin-coated carbide cutting tool having four flute 8mm diameter, shank length 30mm and cutter length 35mm For surface roughness measurement Surtronic3^{+} was used which has diamond stylus tip with accuracy of 0.005µm and resolution of 1.0µm horizontal, 10nm vertical and having a maximum measuring range of 25mm.

Table 1. Selected parameters and Levels

Factors	Level 1	Level 2	Level 3
Speed(m/min)	13.70	19.22	26.90
Feed(mm/min)	20	31.50	50
Depth of Cut(mm)	0.4	0.8	1.2

To obtain a reliable database, each experiment is replicated three times and the mean values were calculated. These are shown in table no.2 After all experiments are conducted, decisions must be made concerning which parameters affect the performance of a process and a mathematical model is developed to predict output amounts close to the actual amounts. According to the Taguchi method, the S/N ratio is the ratio of signal-to-noise where signal represents the desirable value (i.e. the mean for the output characteristic), and noise represents the undesirable value (i.e. the square deviation for the output characteristic). Therefore, the S/N ratio is the ratio of mean to square deviation. Its unit is dB. The S/N ratio for each experimental run is calculated by using the following equation (1).

$$S/N = -10\log\,[MSD] \quad (1)$$

MSD stands for mean square deviation, which is also a measure of the dispersion of the data. Shown in table no.2

Table 2. Response and S/N Ratio for Surface Roughness

Experiment no.	Speed (m/min)	Feed (mm/min)	Depth of cut (mm)	Mean Surface roughness (µm)	S/N Ratio
1	13.7	20	0.4	1.96	-5.84512
2	13.7	31.5	0.8	1.85	-5.34343
3	13.7	50	1.2	1.65	-4.34968
4	19.22	20	0.8	1.90	-5.57507
5	19.22	31.5	1.2	1.88	-5.48316
6	19.22	50	0.4	1.45	-3.22736
7	26.9	20	1.2	1.31	-2.34543
8	26.9	31.5	0.4	1.27	-2.07607
9	26.9	50	0.8	1.17	-1.36372

Table 3. Response Table for Signal to Noise Ratio Smaller is better

Level	Speed	Feed	Depth of cut
1	-5.179	-4.589	-3.716
2	-4.762	-4.301	-4.094
3	-1.928	-2.980	-4.059
Delta	3.251	1.608	0.378
Rank	1	2	3

III. RESULT

Table 4. Analysis of Variance for surface roughness

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Speed	2	0.57416	0.57416	0.28708	21.51	0.044
Feed	2	0.15242	0.15242	0.07621	5.71	0.149
Depth of cut	2	0.00996	0.00996	0.00498	0.37	0.728
Error	2	0.02669	0.02669	0.01334		
Total	8	0.76322				

Results from table 3 shows that the main factors that significantly influence that contributing to surface roughness is the spindle speed. Analysis of variance (ANOVA) for surface roughness is performed to study influence of the end milling process variables. The results for ANOVA performed for surface roughness are shown in table 4. A check of the normality assumption may be made by constructing the normal probability plot of the residuals. Figure 1 depicts normal plot of residuals. This plot is used to test the normal distribution of errors. If the underlying error distribution is normal, this plot will resemble a straight line. This distribution shown in figure 1 presents that the error normality assumption is valid. The same figure shows plotting of the residuals in time order of data collection. This method is helpful in checking independence assumption on the residuals. It is desired that the residual plot should contain no obvious patterns. Figure presents that independence assumption on the residuals was fulfilled for this experiment. This figure also shows plot of residual versus fitted values. The structure less distribution of dots above and below the abscissa (fitted values) shows that the errors are independently distributed and the variance is constant. Therefore it can be concluded that the assumption of constant variance of residuals was satisfied. Now those assumptions are proved not to be violated through this experimentation it can be relying on ANOVA results. More observation shows that, the changing of the spindle speed would affect the surface roughness. Therefore, increasing the spindle speed will reduced value of surface roughness and reducing the spindle speed will increased the value of surface roughness. It was found from figure 2 that the spindle speed with 26.9 m/min, 50mm/min of the feed rate and 0.4mm depth of cut can achieve the minimum value of surface roughness. The optimal factor levels obtain from main effects plot of S/N Ratio for surface roughness is shown in table 5. The optimal combination of the machining parameters has been determined in the previous analysis. However, the final step of Taguchi's parameter design is to predict and verify the improvement of the performance characteristics with the selected optimum machining parameters.

Table 5. Optimal Factor Levels for Surface Roughness

S.No.	Factor	Optimum level	Optimum value
1	Speed(m/min)	3	26.90
2	Feed(mm/min)	3	50
3	Depth of cut(mm)	1	0.4

The estimated average value for surface roughness can be calculated using the following prediction equation (2)

$$\eta_{opt} = \eta m + (S3 - \eta m) + (F3 - \eta m) + (D1 - \eta m) \quad (2)$$

Where, η_{opt} = predicted optimum surface roughness average, ηm = overall average of all the experimental data for surface roughness and S3, F3 and D1 are the responses at the optimum levels of all the main effects. The results of the experimental confirmation for surface roughness using the optimal machining parameters are shown in table 6. This table also represents the actual reduction in the average value of surface roughness for each optimal setting with respect to the chosen initial setting (S1, D1, F1). It shows the comparison of the predicted surface roughness with the actual surface roughness using the optimal machining parameters. The experimental results confirm the validity of the utilized Taguchi method for improving the machining performance and optimizing the machining parameters. Confirmation test results proved that the determined optimal combination of machining parameters, with respect to the reference parameters, satisfy the real requirement of End Milling operations for the proper machining of EN 19.

In this study Taguchi parameter design was successfully used to optimize the control factors of End Milling process. It was found that the spindle speed with 26.9 m/min, 50mm/min of the feed rate and 0.4mm depth of cut can achieve the minimum value of surface roughness. The main factor that significantly influences that contributing to surface roughness is the spindle speed. More observation shows that, the changing of the spindle speed would affect the surface roughness. Therefore, increasing the spindle speed will reduced value of surface roughness and reducing the spindle speed will increased the value of surface roughness. The results show that Taguchi design is an effective tool for process optimization.

Figure 1. Residual plots for surface roughness

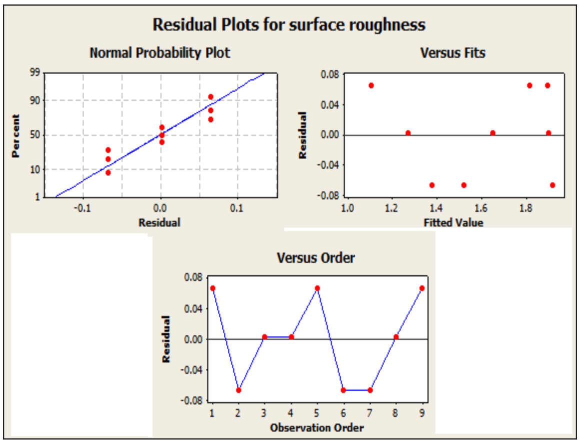

Figure 2. Main Effect Plot for S/N Ratios of Surface Roughness

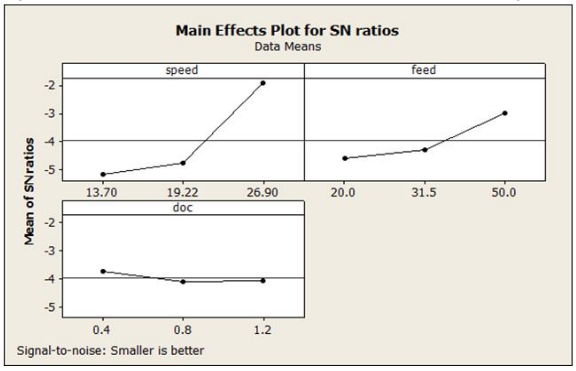

Table 6. Experiment confirmation for Surface Roughness

	Initial machining parameter	Optimal machining parameter		Reduction in surface roughness
		Prediction	Experiment	
Parameter level	S1 F1 D1	S3 D3 F1	S3 F3 D1	
Surface roughness(µm)	2.18, 2.10, 2.14		1.20, 1.15, 1.11	
Average	2.14	1.033	1.15	0.99µm(0.462 times)

REFERENCES

[1] Aminollah Mohammadi, Alireza Fadaei Tehrani, Ehsan Emanian, Davoud Karimi, statistical analysis of wire electrical discharge turning on material removal rate, Journal of Materials Processing Technology 205, 283- 289,2008.

[2] K. Kanlayasiri, S. Boonmung ,An investigation on effects of wire-EDM machining parameters on surface roughness of newly developed DC53 die steel, journal mate Process.technol.187,26-29, 2007.

[3] Arokiadas R., K. Palaniradja and N. Alagumoorthi. Prediction and optimization of end milling process parameters of cast aluminium based MMC. Trans. Nonferrous Met. Soc. China. 22, 1568-1574, 2012.

[4] Baharudin B.T.H.T, M.R. Ibrahim, N. Ismail, Z. Leman, M.K.A. Ariffin and D.L. Majid. Experimental Investigation of HSS Face Milling to AL6061 using Taguchi Method. Procedia Engineering, 50, 933 – 941, 2012.

[5] Lin Tsann-Rong Experimental design and performance analysis of TiN-coated carbide tool in face milling stainless steel. Journal of Materials Processing Technology, 127, 1-7 2002.

[6] Ting-Cheng Chang, Feng-Che Tsai, Jiuan-Hung Ke, Data mining and Taguchi method combination applied to the selection of discharge factors and the best interactive factor combination under multiple quality properties, Int J Adv Manuf Technol 31: 164–174, 2006.

[7] S. S. Mahapatra, Amar Patnaik, Optimization of wire electrical discharge machining (WEDM) process parameters using Taguchi method, Int J Adv Manuf Technol 34:911–925, 2007.

[8] Aminollah Mohammadi, Alireza Fadaei Tehrani, Ehsan Emanian, Davoud Karimi, A new approach to surface roughness and roundness improvement in wire electrical discharge turning based on statistical analyses, Int J Adv Manuf Technol 39:64–73, 2008.

[9] Douglas C. Montgomery, Design and Analysis of Experiments, john wiley and sons 2001.

[10] Vishal Parashar, A.Rehman, J.L.Bhagoria, Y.M.Puri, Investigation and optimization of surface roughness for wire cut electro discharge machining of SS 304L using Taguchi dynamic experiments, International Journal of Engineering studies, volume 1 Number 4, pp. 257-267, 2009.

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