Optimization of End Milling Process Parameters on Surface Roughness of EN19 Steel by Taguchi Method

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Abstract— The present work is associated with End milling of En-19 steel. The paper represents the influences of different cutting parameters like cutting speed feed and depth of cuts on surface roughness of the En-19 steel. 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 50mm×32mm×19 mm as the work piece. Tin-coated carbide cutting tool having four flute 12mm diameter, shank length 30mm and cutter length 35mm is used for experiment on a vertical milling machine . 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. Analysis of variance (ANOVA) was employed to analyse the effect of these milling parameters. The analysis results revealed that the depth of cut 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.

Key words: Analysis of Variance (ANOVA), Milling, Surface Roughness, Taguchi Method

I. Introduction

As a basic machining process, End milling is one of the most widely used metal removal processes in industry and milled surfaces are largely used to mate with other parts in die, aerospace, automotive, and machinery design as well as in manufacturing industries to improves fatiguestrength, corrosion resistance, or creeplife. Surface roughness is an important measure of the technological quality of a product and a factor that greatly influences manufacturing cost [1, 2]. The mechanism behind the formation of surface roughness is very dynamic, complicated, and process dependent; it is very difficult to calculate its value through theoretical analysis [3], therefore, machine operators usually use “trial and error” approaches to set-up milling machine cutting conditions in order to achieve the desired surface roughness. Obviously, the “trial and error” method 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. 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.[4] 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. [5]

II. Experimental Method

The experiment of end milling is carried out on a vertical milling machine BMV45+ equipped with maximum spindle speed of 8000 rpm; maximum feed 800mm/minute. The work material used was steel grade EN19 in the form of a 50mm×32mm×19mm 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:

Parameters	Levels		
	A	B	C
Cutting Speed (m/min)	80	85	90
Feed rate (mm/revo)	0.14	0.18	0.22
Depth of cut (mm)	0.3	0.4	0.5

Based on Taguchi design L9 orthogonal array of has been selected for the experiments in MINITAB 18. All these data are used for the analysis and evaluation of the optimal parameters combination. The selected L9 orthogonal array is shown below:

Experiment no.	Cutting speed (m/min)	Feed rate (mm/ rev.)	DOC(mm)
1	80	0.14	0.3
2	80	0.18	0.4
3	80	0.22	0.5
4	85	0.14	0.4
5	85	0.18	0.5
6	85	0.22	0.3
7	90	0.14	0.5
8	90	0.18	0.3
9	90	0.22	0.4

III. RESULT AND DISCUSSION

The result of ANOVA analysis for Surface roughnessTable1. Shows that the feed (6.96%) and Depth of cut (59.433%) have the highest influence on the surface roughness. The interaction between them is also significant. The cutting speed is influencing comparatively less (.7932%), which indicates that there is no appreciable increase surface roughness by increasing the speed.

Source	DOF	Sum of Squares	Mean of Squares	F Value	P Value	% Contribution
Speed	2	0.000028	0.000014	0.02	0.976	0.7932
Feed	2	0.000246	0.000123	0.21	0.825	6 .96
DOC	2	0.002098	0.001049	1.81	0.356	59.433
Error	2	0.001158	0.000579			32.8138
Total	8	0.003530				100

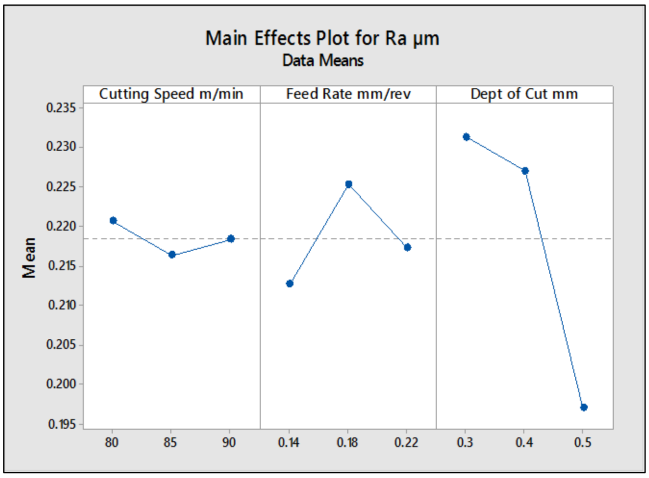
Table 1: Results of ANOVA analysis for Surface roughness

A. *Model Summary*

S	R-sq	R-sq(adj)
0.0185538	51.24%	21.99%

1) *Main Effects Plot:*

From the main effect plot for means it is observed that surface roughness is a function of Cutting speed, Feed, and Depth of cut. The cutting speed and feed rate have more impact on surface roughness. These Taguchi results compared with regression analysis shows close agreement. The main effect plots for parameters such as cutting speed .feed and DOC is obtained from regression analysis using Minitab Version 18 statistical software to predict the optimum level for response measured.



Graph 1: Main effects plot for surface roughness

2) *Linear Regression Models:*

a) Regression Analysis:

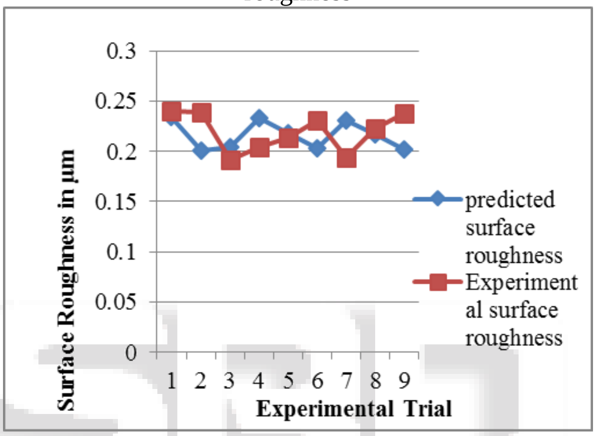
Surface roughness versus cutting speed, feed, and depth of cut

To establish the correlation between the process parameters (1) cutting speed , (2) Feed and (3) Depth of cut and surface roughness a linear regression model was obtained using statistical software "MINITAB R 18".The terms that are statistically significant are included in the model. Final Equation obtained is as follows,

Surface roughness =0.296 - 0.00023 Cutting Speed m/min + 0.058 Feed Rate mm/rev- 0.1717 Depth of Cut mm [1]

Sr. No.	Predicted surface roughness Ra in µm	Experimental surface roughness Ra in µm
1	0.234	0.24
2	0.201	0.239
3	0.204	0.192
4	0.233	0.204
5	0.218	0.214
6	0.203	0.231
7	0.231	0.194
8	0.217	0.223
9	0.202	0.238

Table 2: Comparison of experimental and predicted surface roughness



Graph 2: Predicted VS. Experimental Surface roughness

3) *Confirmation Test:*

To test the efficiency of the model the confirmation tests were performed by selecting the set of parameters as shown in table 4.4 Surface roughness and table 4.7 for hardness of needle. Table 4.7 shows the comparison of temperature rise results from the mathematical model developed in the present work equation (1) with values obtained experimentally respectively. By comparing the results of values obtained from temperature rise equation and results of confirmation test, we have concluded that the confirmation test holds the equation for the values which are not included in the orthogonal array. It can be observed from table 4.7 that the calculated error varies from 10% to 11% for temperature rise. Therefore the multiple regression equation derived above correlate the evaluation of temperature rise with the degree of approximation.

Sr. No.	Parameter	Optimum level
1	Cutting Speed	85 m/min
2	Feed Rate	0.14mm/rev
3	Depth of cut	0.5mm

Parameter	Model value	Experimental value	Error %
Surface roughness	0.1987	0.1890	4.88

Table 4: Confirmation Experiment Result of Surface roughness

IV. CONCLUSION

The present work has successfully demonstrated the application of Taguchi method for optimization of process parameters in End milling of EN19 alloy steel.

The surface roughness (Ra measured under different cutting conditions for diverse combinations of machining parameters. The important conclusions drawn from the present work are summarized as follows:

1) The optimal cutting parameters for the machining process lies at 85 m/min for cutting speed, 0.14 mm/revolution for feed rate and 0.5 mm for depth of cut.
2) Analysis of variance shows that depth of cut is the most significant machining parameter followed by cutting speed, affecting selected response characteristics i.e. surface roughness.
3) The cutting speed and feed rate has least influence on surface roughness.
4) The percentage of error between the predicted and experimental values of the multiple performance characteristics during the confirmation experiments is Less than 5 % as it is within limit
5) Taguchi grey relational analysis does not involve any complicated mathematical theory or computation and thus can be employed by the engineers without a strong statistical background.

REFERENCES

[1] T.S. Lee, Y.J. Lin, A 3D predictive cutting force model for end milling of parts having sculptured surfaces, Int. J. Adv. Manuf. Tech. 16 (2000) 773–783.

[2] Y. Altintas, Direct adaptive control of end milling process, Int. J. Mach. Tool Manuf. 34 (4) (1994) 461–472.

[3] Y.H. Tsai, J.C. Chen, S.J. Lou, In-process surface recognition system based on neural networks in end milling cutting operations, Int. J. Mach. Tool Manuf. 39 (4) (1999) 583–605.

[4] Vishal Parashar and Rajesh Purohit , “Investigation of the effects of the Machining Parameters on Material Removal Rate using Taguchi method in End Milling of Steel Grade EN19” 5th International Conference of Materials Processing and Characterization (ICMPC 2016) Materials Today: Proceedings 4 (2017) 336–341

[5] Julie Z. Zhang, Joseph C. Chen, E. Daniel Kirby, “surface roughness optimization in an end-milling operation using the taguchi design method” journal of materials processing technology 184 (2007) 233–239 (2006

[6] J.A. Ghani a, I.A. Choudhury, H.H. Masjuki, “Performance of P10 TiN coated carbide tools when end milling AISI H13 tool steel at high cutting speed,” Journal of Materials Processing Technology, 2004