Assessment Of Cutting Parameters For Optimization Of Material Removal Rate In Face Milling Operation: Taguchi Method And Regression Analysis

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Abstract

The present research work discusses about the application of Taguchi method and Regression Analysis for optimization of Material Removal Rate in machining of Gun metal with a HSS tool. The experiment was designed using Taguchi's experimental design technique. The cutting parameters selected are spindle speed, feed and depth of cut. The effect of cutting parameters on Material Removal Rate is investigated and the optimum cutting conditions for maximizing the Material Removal Rate is determined. Linear regression equation is developed with an objective to establish a correlation between the selected cutting parameters and Material Removal Rate. The predicted values are compared with experimental values and are found to be in good agreement. Depth of cut is found to be the most influencing factor affecting Material Removal Rate followed by spindle speed and feed.

Keywords: Taguchi method; Regression Analysis; Material Removal Rate, Gun Metal.

1. Introduction

Considering the current scenario of manufacturing industries, it has become vital for every firm to meet the demands in minimum span of time. It is worthwhile important to study the rate at which the material is being removed and at the same time achieving the quality requirements. The volume of material removed per minute in machining of a component is termed as material removal rate. The present work investigates the effect of cutting parameters on Material removal rate in face milling operation in a CNC machine, in order to find the optimum combination of the parameters to maximize the Material removal rate. The experiment was designed using Taguchi method. Dr. Taguchi employed design of experiments (DOE), which is one of the most important and efficient tools of total quality management (TQM) for designing high quality systems at reduced cost. Taguchi emphasizes on the fact that Quality provides robustness and immune to the uncontrollable factors in the manufacturing state. This approach helps to reduce the large number of experimental trials when the number

of process parameters increases [1]. A L_{27} orthogonal array was selected and the three Process parameter viz. depth of cut, feed and spindle speeds were varied to analyze the results obtained. Regression analysis is applied to develop a linear regression equation.

2. Taguchi Methodology

Taguchi method is based on performing evaluation or experiments to test the sensitivity of a set of response variables to a set of control parameters (or independent variables) by considering experiments in "orthogonal array" with an aim to attain the optimum setting of the control parameters. Orthogonal arrays provide a best set of well balanced (minimum) experiments [2]. These experiments provide full information about all the factors that affect the response parameter [3]. Taguchi method stresses the importance of studying the response variation using the signal – to – noise (S/N) ratio, resulting in minimization of quality characteristic variation due to uncontrollable parameter. Larger the better characteristic is used for calculation of S/N ratio for Material Removal Rate.

$$\frac{S}{N_{(Bigger)}} = -10 \log \left(\frac{\Sigma \left(1/y_i^2 \right)}{n} \right)$$

Where n is the number of measurement in a trail/row and Yi is the measured value in the run/row.

3. Materials and Methods

The work material used in the present investigation is a gun metal rectangular block of 80 X 80 X 40 mm. The chemical composition consists of (88%) copper, (10%) tin and (2%) zinc. Figure 1 shows the experimental set up for face milling operation. A L_{27} orthogonal array is employed for conducting the experimental runs and MRR is calculated for each run. Taguchi's method is used to design the experiment. The three cutting parameters selected for the present research work are spindle speed (S), feed (f) and depth of cut (d), with three level tests for each factor. Table 1 represents the machining parameters used and their levels chosen.

Figure 1: Experimental set up for milling operation

Table 1: Machining parameters and their levels

Parameters	Level1	Level2	Level3
Spindle speed (rpm)	600	800	1000
Feed (mm/rev)	40	50	60
Depth of cut (mm)	0.2	0.4	0.6

All the experiments were done with a HSS tool on a CNC XL mill with following specifications: Machine dimensions L x B x H (1000 x 575 x 650) mm, programmable feed rate from 0 – 1200 mm/min, spindle speed 150 – 4000 rpm, table size 360 x 132mm, and axis motor capacity 0.8 Nm.

4. Results and Discussion

4.1 Effect of machining parameters on Material removal Rate

Experiments were conducted with three parameters at three different levels. Table 2 shows the results obtained for Material Removal Rate and the corresponding S/N ratios.

Table 2: Experiment results for Surface roughness

Exp. No.	speed (rpm)	feed (mm/rev)	doc (mm)	MRR (mm^3/min)	S/N Ratio
1	600	40	0.2	241152	107.646
2	600	40	0.4	482304	113.666
3	600	40	0.6	723456	117.188
4	600	50	0.2	301440	109.584
5	600	50	0.4	602880	115.605
6	600	50	0.6	904320	119.126
7	600	60	0.2	361728	111.168
8	600	60	0.4	723456	117.188
9	600	60	0.6	1085184	120.710
10	800	40	0.2	321536	110.145
11	800	40	0.4	643072	116.165
12	800	40	0.6	964608	119.687
13	800	50	0.2	401920	112.083
14	800	50	0.4	803840	118.103
15	800	50	0.6	1205760	121.625
16	800	60	0.2	482304	113.666
17	800	60	0.4	964608	119.687
18	800	60	0.6	1446912	123.209
19	1000	60	0.2	602880	115.605
20	1000	60	0.4	1205760	121.625
21	1000	60	0.6	1808640	125.147
22	100	50	0.2	502400	114.0

	0				21
23	1000	50	0.4	1004800	120.042
24	1000	50	0.6	1507200	123.563
25	1000	40	0.2	401920	112.083
26	1000	40	0.4	803840	118.103
27	1000	40	0.6	1205760	121.625

Table 3 shows the S/N ratio obtained for different parameter levels. Depth of cut was found to be the most influencing parameter with highest delta value of 9.5 followed by Spindle speed and Feed with 4.4 and 3.5 delta values respectively. Figure 2 shows the main effect plot for S/N ratio. The greatest variation found on Material Removal Rate was due to Depth of cut. The optimum conditions for Material Removal Rate are spindle speed of 1000 rpm, depth of cut of 0.6 mm and feed of 60 mm/rev.

Table 3: Response Table for Signal to Noise Ratios (Larger is better)

Level	**Spindle Speed (rpm)**	**Feed (mm/rev)**	**Doc (mm)**
1	114.7	115.1	111.8
2	117.2	117.1	117.8
3	**119.1**	**118.7**	**121.3**
Delta	4.4	3.5	9.5
Rank	2	3	1

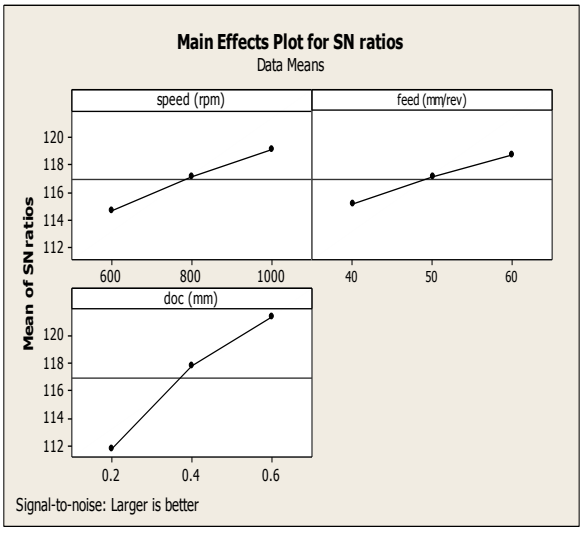

Figure 2: Effect of spindle speed, feed and depth of cut on Material Removal Rate

4.2 Regression Analysis

The spindle speed, feed and depth of cut are considered in the development of mathematical model for Material Removal Rate. The correlation between the cutting parameters and MRR is obtained by linear regression; equation 1 shows the developed model.

MRR = - 1875627 + 1172 speed (rpm) + 18756 feed (mm/rev) + 2009600 doc (mm) (1)

The predicted and the experimental values of Material Removal Rate are shown in figure 3. It is clear from the figure that most of the predicted values are in close agreement with the experimental values for Material Removal Rate.

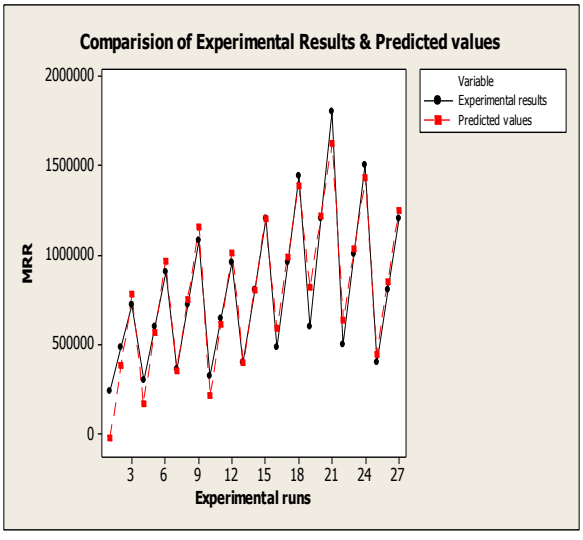

Figure 3: Comparison between experimental and predicted values

5. Conclusion

The study discusses about the application of Taguchi method and Regression Analysis to investigate the effect of process parameters on Material Removal rate. From the analysis of the results obtained following conclusion can be drawn: -

- Statistically designed experiments based on Taguchi method are performed using L27 orthogonal array to analyze Material Removal rate.
- Optimal parameters for Material Removal rate are Depth of cut of 0.6mm, Feed rate of 60mm/rev and spindle speed of 1000 rpm.
- Linear regression equation is developed to predict the values of Material Removal rate, and the predicted values are compared with the measured value.

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