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Optimization in Cutting Parameters for Milling Operation for the Material Mild Steel JRC-235J+C

M. Tech. Scholar Anish Kumar, Associated Professor Mr. Onkar Mal
Dept.of Mechanical Eng.
Dr. K.N. Modi University, Newai(Rajasthan)

Abstract- **The objective of this research work is to provide statistical evidence for optimizing parameters to improve the surface roughness. For that an experimental investigation is done by producing a workpiece of Stainless steel on a CNC milling machine tool. The cutting material used for it is made of carbide which is generally used in production. Taguchi method and ANOVA were used for enhancing the machining performance and optimizing the machining parameters for CNC Milling. The Minitab-19 is employed to analyze the Taguchi and ANOVA methods. An array-L9 was generated to obtain the combination of parameters for the experiment. The parameters investigated were Feed rate, Cutting speed and Depth of cut. The optimised factors identified as Cutting Speed 35 m/minute, Feed rate 200 mm/minute and depth of cut 1 mm. These parameters are worked out to improve the surface roughness of the stainless steel.**

Keywords- CNC **Milling, ANOVA, taguchi methods, surface roughness, cutting speed.**

I. INTRODUCTION

Milling is a material removable process to remove excess material from the workpiece. There are various operations for milling such as Facing, End milling, Side Milling, etc.

Figure 1. Milling operation.

There are three main cutting parameters which are most responsible for metal cutting. These are cutting speed , feed rate and depth of cut.

In case of point machining such as drilling, reaming , boring and tapping, only two parameters, cutting speed and fed rate are more preferable.

1. Cutting speed:
Cutting speed is a peripheral speed of tool at which it cuts the material and the cutting speed is expressed in meter per minute as underneath:-

$$Vc= \pi DN/1000 \text{ m/minute}$$

Where Vc: cutting speed
D: tool dia
N: RPM (revolution per minute)

2. Feed rate:
It is relative linear motion at which tool penetrates the workpiece. The unit of feed rate is mm/revolution.

3. Depth of Cut:
Depth of cut is the material removal rate, which is the volume of workpiece material (metal, wood, plastic, etc.) that can be removed per time unit.

4. Problem formulation
Bhartiya skill development university is India's first skill university which is working to make the indian youth skillful. In the department of manufacturing , it is observed that most of the students have complaints regarding reaming operation.

Students follow the same procedure as explained by experts but most of the workpieces got rejected because of reaming operations in the quality checking. To decrease the chances of rejection, the study is accompanied with the objective as referenced underneath.

5. Objectives of the study
To optimize the cutting parameters for Milling operation to reduce the probability of rejection with the help of ANOVA and Regression analysis.

II. LITERATURE REVIEW

T. M. Hossainy et al.(2010), had a study that flank wear in the cutting edge of tools increases the machining time. His study is based on the three variables flank wear, cutting force and surface roughness. He found as a result that cutting force and surface roughness have dependency compared to flan wear.

C. Manikandan and B. Rajeswari (2013), investigated that production cost is influenced by the machining operation and its cycle time. And said that tool selection depends on the specific operation and on the work material. He used high speed steel tools material for the drilling operation on the EN24 material. The ANOVA and taguchi techniques are taken into consideration for the study.

Ramazan and Adem AcırIn (2013), had an experimental study about effect of temperature on Al 7075 work piece and the uncoated and Firex coated carbide drills in the experiment were used.. For the completion of the study , the taguchi method is used. And a regression analysis is done to get the relation between the variables and it is compared with the results obtained in the experiment.

Roshani U. Shingarwade (2013), had an investigation on reaming operation with two types of coolant based on mineral to get the optimum combination of parameters, spindle speed, feed rate, reverse feed rate, for the better surface roughness of gray cast iron SAE D7003 and K20 cemented carbide tools is used as a cutting material. The data analysis is done with the help of the Taguchi L9 orthogonal array and the results clears that a desirable quality is achieved using these variables high spindle speed, low feed rate and low reverse feed rate.

III. DESIGN OF EXPERIMENT

The Taguchi method is used for the design of experiments and ANOVA is used for the data analysis.

1. Taguchi method:
Taguchi recommends the use of loss functions to determine process response deviation from the desired value. The value of the loss function is further converted into signal-to-noise(S/N) ratio and tries to select the parameter levels that maximize this ratio. The term signal represents the square of the mean of the quality characteristic while noise is a measure of the variability of the characteristic. There are three categories of output characteristic in the analysis of S/N ratio, these are: Higher-the-better, lower-the-better and nominal-the best. The S/N ratio can be evaluated by following formula:

For nominal the best S/N T = 10log ()
For Higher-the-better S/NL = -10 log Σ 2)
For lower-the-better S/NS = -10 log Σ 2)

Where y is the observed data and n is the number of observations.

2. Selection of variables
In this study we have considered three factors shown in table 6 which affect majorly on quality cycle time such as –

- Cutting Speed
- Feed Rate
- Depth of Cut

Table 1.

Factors	Level 1	Level 2	Level 3
Cutting Speed (m/minute)	25	30	35
Feed (mm/minute)	200	300	400
Depth of cut (mm)	0.5	0.75	1

3. Taguchi Design
- Taguchi Orthogonal Array Design L9(3**3)
- Factors: 3
- Runs: 9

Table 2. Orthogonal L9 Array.

Cutting Speed	Feed rate	Depth of cut
25	200	0.5
25	300	0.75
25	400	1
30	200	0.75
30	300	1
30	400	0.5
35	200	1
35	300	0.5
35	400	0.75

IV. EXPERIMENTAL RESULT

In order to produce more reliable information from the statistical analysis of the experiment three repeated tests were conducted according to the L9 orthogonal array. The experimental studies were performed. Different settings of cutting speed, feed rate and depth of cut are shown in the given table 8. The size of the product is 100 mm× 60 mm×20 mm produced in the experiments.

Each combination of control factors of the orthogonal array has a total of three tests. The experimental results are shown in Table 8 the performance of each experimental arrangement is evaluated by computing their S/N ratio. In the present work a software MINITAB -19 is used for the calculation of S/N ratio and ANOVA. The software MINITAB -19 is first confirmed for its accuracy by matching the results of similar types of problems in the literature.

Table 3. experimental result.

S.N	Cutting Speed	Feed	Depth of Cut	RA	SNRA1	MEAN1
1	25	200	0.5	1.625	**-4.217067306**	1.625
2	25	300	0.75	3.003	-9.551106644	3.003
3	25	400	1	3.874	-11.76319233	3.874
4	30	200	0.75	1.231	**-1.805161059**	1.231
5	30	300	1	3.124	-9.894220504	3.124
6	30	400	0.5	3.765	-11.51529961	3.765
7	35	200	1	1.114	**-0.937703817**	1.114
8	35	300	0.5	2.232	-6.973883805	2.232
9	35	400	0.75	3.398	-10.62446749	3.398

1. Response Table for Signal to Noise Ratios Smaller is better.

Table 4. Response table for SN Ratio.

Level	Cutting speed	Feed rate	Depth of cut
1	-8.51	**-2.32**	-7.569
2	-7.731	-8.806	**-7.327**
3	**-6.179**	-11.301	-7.532
Delta	2.332	8.981	0.242
Rank	2	1	3

2. Main Effects Plot for SN ratios

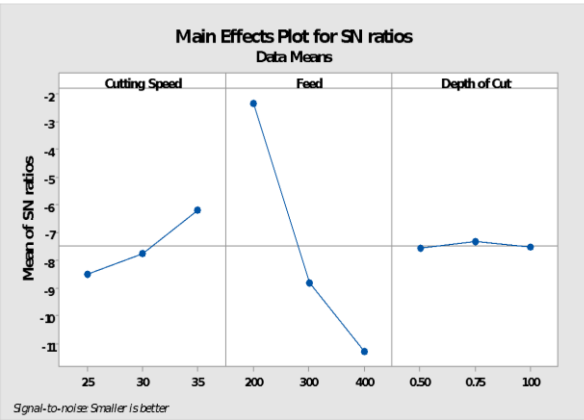

Figure3. main effect plot for S.N ratio

It is clear by figure 28 that "feed rate is the most affecting factor (Dealt-8.981) for the roughness and "cutting speed" with (Delta-2.332) is the second most important factor. From table 9 it is clear that "depth of cut" (rank -3) has the least effect on cycle time.

Analysis of Variance (ANOVA) is a hypothesis-testing technique used to test the equality of two or more populations (or treatment) means by examining the variances of samples that are taken. ANOVA allows one to determine whether the differences between the samples are simply due to random error (sampling errors) or whether there are systematic treatment effects that cause the mean in one group to differ from the mean in another. Most of the time ANOVA is used to compare the equality of three or more means, however when the means from two samples are compared using ANOVA it is equivalent to using a t-test to compare the means of independent samples. ANOVA is based on comparing the variance (or variation) between the data samples to variation within each particular sample. If the between variation is much larger than the within variation, the means of different samples will not be equal. If the between and within variations are approximately the same size, then there will be no significant difference between sample means.

Table 5. anova design.

Null hypothesis	All means are equal
Alternative hypothesis	Not all means are equal
Significance level	α = 0.05

Table 6. ANOVA table.

Cutting	DF	Adj SS	Adj MS	F-Value	P-Value
Cutting speed	2	0.56998	0.28499	5.01	0.166
Feed rate	2	8.48639	4.24319	74.63	**0.013**
Depth of cut	2	0.05229	0.02614	0.46	0.685
error	2	0.11371	0.05685		
total	8	9.22237			

Table 6 shows the results of ANOVA for surface roughness. From the results, it is observed that the feed is the most significant parameter followed by cutting speed and depth of cut has less significance in controlling the surface roughness values. From the ANOVA table, p-value of feed rate (0.013) which is less than 0.05. It means that feed's influence significantly on workpiece surface roughness between three cutting parameters.

Regression analysis is a statistical method for approaching the relationships between variables. It is a method for modelling different variables. It helps to understand how the dependent variable turns when any one of the independent variables is changed. Regression analysis was carried out for surface roughness taking cutting speed, federate and depth of cut as independent variables and surface roughness as a dependent variable. Normal probability of regression equation are also plotted in Figure 30 for surface roughness

3. Regression Equation

Surface

Roughness=2.5962+ 0.238 Cutting Speed_25+0.110 Cutting Speed_30-0.348 Cutting Speed_35- 1.273 Feed_200+ 0.190 Feed_300+ 1.083 Feed_400- 0.056 Depth of Cut_0.50-0.052 Depth of Cut_0.75+ 0.108 Depth of Cut_1.

CONCLUSION

Experimental investigation on the EMCO concept mill-250 has been done using the Taguchi method. The method has been successfully applied for finding out the relative contributions of various factors such cutting speed, feed rate and depth of cut for surface roughness and for finding out the optimum factor level combinations Based on the experimental results. The following conclusions are made:

- The most significant factors affecting the surface roughness have been identified as feed rate and the cutting speed.
- The following factor settings have been identified to yield the best combination of process variables: "Feed rate 200 mm/minute, cutting speed 35 m/minute and depth of cut 1 mm"
- Level of effect of parameters is feed rate , cutting speed and depth of cut as defined by the response table for SN ratio which obtained rank 1, 2, 3 respectively
- Experimental as well as predicted S/N ratios at optimum level are nearly equal to each other and therefore confirm the success of the experiment.
- The experimental results confirmed the validity of the used Taguchi method for enhancing the machining performance and optimizing the machining parameters.
- Future Scope
- The present work can be extended further for different conditions of process parameters at different levels for different materials.
- The present work can be done by taking PVD or CVD coated tools rather than carbide.
- In this research we have studied the responses of surface roughness. It may be extended to optimize the material removal rate. There are many other responsive characters to be studied.
- In this research we have used taguchi technique for optimising Surface Roughness. There are other techniques which can be used for the study. We have studied the parameters under high speed machining conditions of stainless steel.

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