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RATE OF MATERIAL REMOVAL AND SURFACE ROUGHNESS MODELING AND OPTIMIZATION IN CNC MILLING FOR MILD STEEL USING TAGUCHI TECHNIQUE

Engineering

KEYWORDS: Taguchi technique, NC milling center (VMC), machining parameters, Surface roughness, material removal rate

Harsimran Singh Sodhi	Asst. Prof. Chandigarh University Gharuan,
Dr. Bikram Jit Singh	Professor at MMU, Sadopur,Ambala
Dr. Doordarshi Singh	Asst. Prof, BBSBEC Fatehgarh Sahib,

ABSTRACT

In current industrial scenario maximizing the quality of final product is one of the primary concerns of the machining operations in general and in milling particularly. Lesser control over the cutting parameters due to long slot cutting in flats creates the non-conforming parts resulting in increase in cost and loss of productivity due to scrap or rework. The present research work has been done for parametric optimization of milling process i.e. feed rate, spindle speed and depth of cut for aluminium bars on a Computer numerical controlled milling machine with the help of Taguchi technique as design of experiments. Carbide tool is used for milling operation. A series of experiments has been designed by using Taguchi Orthogonal Array L27, estimated regression test, is being used to identify the factors significantly affecting the surface roughness The main response parameters are material removal rate (MRR) and surface roughness. These parameters depend upon the value of spindle speed, feed rate and depth of cut. All these control parameters are directly or indirectly co-related with each other. If the depth of cut is increased then MRR increases, but poor surface finishing is achieved. On the other hand by increasing the cutting speed, material removal rate and surface finishing improves simultaneously. It employs that all the parameters are conflicting so we have to select the optimized parameters for the enhancement of the performance. The optimized results are found by using ANOVA technique.

1.INTRODUCTION

With the more precise demands of modern engineering products, the control of surface texture has become more important. It has been investigated that surface texture greatly influences the functioning of the machined parts. Manufacturing involves a number of processes to convert raw materials into final products to be used for a number of purposes. By using any of the manufacturing technique, it is impossible to produce a perfectly quality of smooth surface but at the same time higher material removal rate (MRR) is of great concern as far as to higher productivity rate is concerned. Hence, the improved surface qualities of manufactured product and the economics of the manufacturing operation are very importantly considered to produce products with functional and visual appeal. In present work study on , the machining parameters such as depth of cut, spindle speed and feet rate that affect the surface roughness and material removal rate in the milling operation has been done. Taguchi's L27 orthogonal array is used to design the experiments regression test has been applied for the process of optimization.

2. LITERATURE SURVEY

From the thourough literature survey it has been observed that [1]a series of experiment have been perfoemed in the in Designing of Experiments to study the effect of cutting parameters such as cutting speed, feed rate and depth of cut on surface Quality in face milling operation. [2] in studied literature it has been found that Taguchi design provides a sequence of procedure which can effectively and identify the optimum surface roughness in the process control of individual end milling machines. [4] it has been mentioned that a number of experiment has been carried out in designing the Experiments to notice the effect of cutting parameters such as cutting speed, feed rate per tooth, feed velocity on tool life, tool wear and surface finish in face milling operation. [5] Investigation has been done to study the effect of the machining parameters, depth of cut in each pass, such as number of passes spindle speed and feed rate to get better surface0020surface finish, dimensional accuracy and tool wear rate. [6] a Genetic Algorithm Proposal approach to find the optimum machining parameters to get good surface finish, life of tool and dimensional tolerance in turning operation. [8] A number of experiment has been carried out in Taguchi's orthogonal array design in which signal to noise ratio and Pareto analysis of variance are done to calculate the effect of milling parameters such as cutting speed, feed rate and depth of cut on surface roughness. [9] Proposed a Grey-Taguchi parameter method to optimize the milling parameters of Aluminiumalloy to get better surface finish.

3. TAGUCHI TECHNIQUE

Taguchi is basically concerned with the quality, which relates to cost, not just only to the manufacturer, but also to the customer and the society as well. As per Taguchi quality is, "The quality of a final product produced is the (minimum) loss imparted by the product to the society from the time product is shipped" .This loss of economy is related with losses due to, wastage of available resources, costs of providing warranty, rework complaints of customer and dissatisfaction, time and money spent by customers on failing products, and revenue losses of market shares. Rigid design is a methodology in engineering for getting a product and good process conditions, which are minimally sensitive to the various causes of variation to produce high quality products having lesser manufacturing costs. Taguchi's parametric design is an important technique to get a rigid design. As it offers simple and a sequential approach to get an optimized design for performance, quality and cost. Two major tools in robust design are, orthogonal arrays and the Signal to Noise ratio. Taguchi's technique is based on statistical design of experiments, and the needs of economy can also be solved by this technique by simply getting the optimized solutions for any given problem. With the help of this technique one can reduce significantly the required time for the investigation of experimental, and to study the effect of individual factors in order to determine which most and the lesser influencing parameters.

In this work smaller the better quality characteristic has been chosen, for the case of surface roughness.

Where,

$S/N=-10\log\Sigma(\sigma 2+Ram2)$……………………I

σ - Standard deviation of surface roughness

Ram - Mean value of surface roughness

Equation I give the relation of signal to noise.

4. RESEARCH GAP

The various effects of the rate of feed, speed of cutting and cutting depth on surface roughness can be reviewed in the literature. In order to optimize the results of various experiments, a number of design of experiments techniques has been used such as response surface method, full factorial method, Taguchi methods, fuzzy logics etc. After that experiments are performed on available set of matrix. ANOVA test and regression tests has also been applied on the available results so that the most influencing parameter can be determined from the whole study.

5. EXPERIMENTATION

The experiments are performed as per available matrix of Taguchi's L27 orthogonal array and material of work piece is Mild Steel having dimensions of (50 mm x 20 mm x 20 mm). The material of tool is coated carbide inserted into a milling machine having diameter of 25 mm. The machining parameters affecting the whole process are considered as cutting Depth, speed of spindle, and Feed rate. Table no 1 shows the selected machining parameters along with limits matrix of Taguchi L27 is shown in table no 3.

Parameter	Lower Limit	Upper Limit
Speed of Spindle (rpm)	700	2100
Rate of Feed (mm/min)	200	600
Cutting Depth (mm)	0.4	1.2

Table1 :- process parameters with limits

S.NO.	Performance Parameters
1	Material Removal Rate (M.R.R)
2	Surface Roughness (Ra)

Table 2:- Output Process parameters From experiment

Spindle speed (Rpm)	Feed rate (mm/min)	Depth of Cut (mm)	MRR (mm^3/min)	Ra (μm)
700	200	0.4	3746.23	1.36
700	200	0.4	3888.889	2.59
700	200	0.4	5462.32	0.92
700	400	0.8	6725.56	3.11
700	400	0.8	2772.53	2.67
700	400	0.8	8888.889	3.53
700	600	1.2	5632.236	1.26
700	600	1.2	5555.556	2.83
700	600	1.2	9777.778	1.22
1400	200	0.8	2936.25	0.85
1400	200	0.8	5079.365	3.43
1400	200	0.8	8452.32	1.59
1400	400	1.2	4325.36	2.71
1400	400	1.2	5079.365	1.68
1400	400	1.2	10666.67	2.13
1400	600	0.4	5986.32	1.97
1400	600	0.4	6854.25	2.05
1400	600	0.4	10056.23	0.86
2100	200	1.2	2857.143	1.15
2100	200	1.2	5079.365	0.53
2100	200	1.2	7619.048	0.96
2100	400	0.4	2666.667	2.52
2100	400	0.4	7111.111	1.53
2100	400	0.4	8965.32	1.17
2100	600	0.8	4235.3	2.38
2100	600	0.8	8526.24	1.19
2100	600	0.8	9756.48	0.89

Table 3 :- Orthogonal matrix of Taguchi L 27

6. TAGUCHI STATIC FOR MATERIAL REMOVAL RATE

First of all the normality check of available data has been checked by probability plot (see first plot of figure 1). As all the data points has been distributed along the normal line and having a very negligible outliers, therefore the data can be considered as normally distributed. The second plot shows that there is no trend while plotting residual versus fitted

Values of data which reflects that chosen Taguchi model is fitted well with given set of data. Third plot shows a frequency histogram having data distribution and last residue versus order plot shows the random data point's distribution which signifies that there is non-significance of experimental order as far as first response MRR is concerned about.

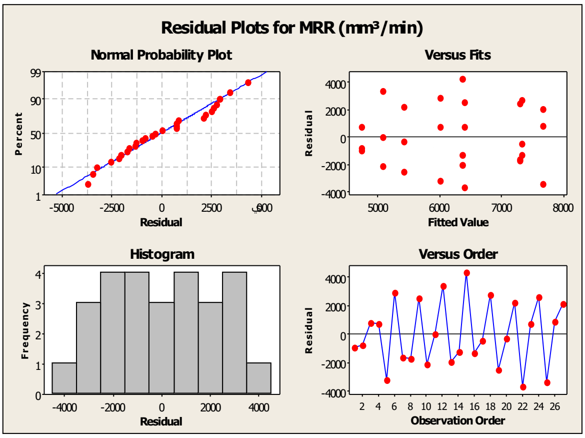

Figure 1:- Residual Plots for MRR (mm3/min)

A. Response Surface Regression: MRR vs Spindle speed & Feed rate
The analysis was done using uncoded units.
Estimated Regression Coefficients for MRR (mm^3/min)

Term	Coef	SE Coef	T	P	Significant/Non Significant
Constant	-253.38	8561.6	-0.030	0.037	Significant
Spindle speed (Rpm)	3.55	7.3	0.486	0.003	Significant
Feed rate (mm/min)	11.33	33.3	0.340	0.017	Significant
Depth of Cut (mm)	2267.46	12492.7	0.182	0.048	Significant
Spindle speed (Rpm)* Spindle speed (Rpm)	-0.86	1.78	-0.485	0.023	Significant
Feed rate (mm/min)* Feed rate (mm/min)*	-1.78	2.89	-0.156	0.018	Significant
Depth of Cut (mm)*Depth of Cut (mm)	-1586.2 5	7.9	-0.200	0.844	Non-Significant
Spindle speed (Rpm)* Feed rate (mm/min)	-1.85	1.36	-0.101	0.046	Significant
Spindle speed (Rpm)*Depth of Cut (mm)	-0.26	4.5	0.058	0.002 5	Significant

R-Sq = 97.93% R-Sq(pred) = 83.25% R-Sq(adj) = 94.86%

Table 4: Regression Coefficient for Ra

A. GRAPHICAL INFERENCES FOR MRR (mm^3/min) FOR STEEL

By using the software Minitab 16, the results in graphical form has been produced. Figure no 3 shows the one factor at a time effect on response MRR.Fig 2 (a) represents that there is an increase in the Material removal rate from speed of 700 rpm to 1400 rpm and decrease from 1400 rpm to 2100 rpm. The maximum value of material removal is found to be at 1400 rpm. Where as in figure 2 (b) the value of MRR increases with the increase in feed rate. Similarly in figure 2 (c) shows that the material removal rate increases when it is increased. Similarly effect of two factors simultaneously on MRR has been shown in figure no 3.

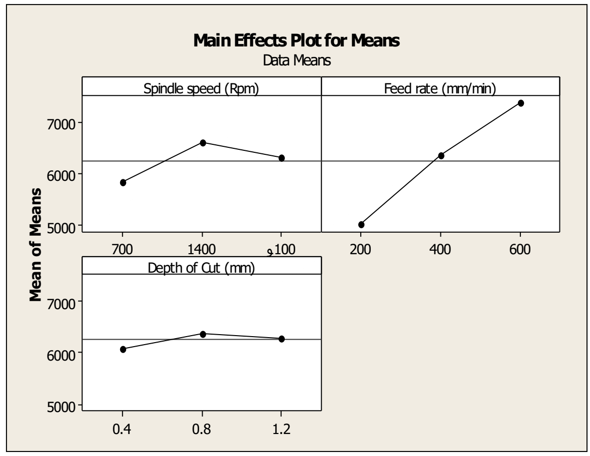

Figure 2:- Main Effects Plot for MRR(mm3/sec)

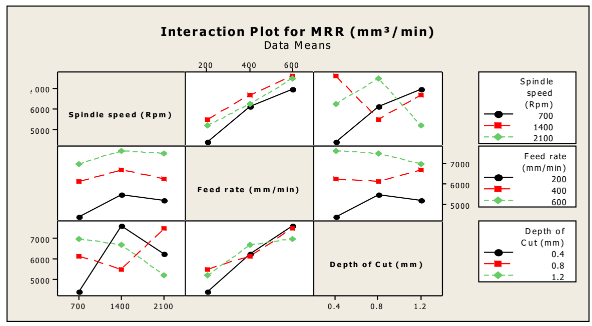

Fig.3 Two-Way Interaction Plot for MRR

7. TAGUCHI STATIC FOR Ra

All the data points are distributed along with the normal line with negligible outliers, therefore available data can be considered as normally distributed. At the same time second plot doesn't have any trend while plotting residual versus fitted values of data which reflects thet Taguchi model is well fitted with given data.

Third plot shows a frequency histogram having even data distribution and last residue versus order plot highlights the random data points distribution which signifies non-significance of experimental order as far as the second response Ra is concerned as shown in figure 4.

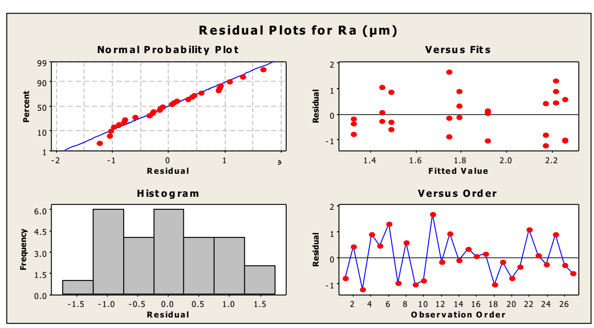

Figure 4:- Residual Plots for MRR (mm3/min)

A. Response Surface Regression: Ra (µm) versus Spindle speed and feed rate

The analysis was done using uncoded units.

Estimated Regression Coefficients for Ra (µm)

Term	Coef	SE Coef	T	P	Significant/Non Significant
Constant	-2.84889	2.47714	-1.150	0.0265	Significant
Spindle speed (Rpm)	0.00047	0.00211	0.223	0.0018	Significant
Feed rate (mm/min)	0.1767	0.00963	1.835	0.0461	Significant
Depth of Cut (mm)	5.5666	3.61452	1.540	0.0014	Significant
Spindle speed (Rpm)* Spindle speed (Rpm)	-1.00265	0.23695	-0.477	0.6392	Non-Significant
Feed rate (mm/min)* Feed rate (mm/min)*	-1.2398	0.257	-0.297	0.0186	Significant
Depth of Cut (mm)*Depth of Cut (mm)	-3.7694	2.29522	-1.637	0.0019	Significant
Spindle speed (Rpm)* Feed rate (mm/min)	-0.2546	0.9653	0.298	0.0563	Non-Significant
Spindle speed (Rpm)*Depth of Cut (mm)	0.00017	0.00131	0.130	0.0096	Significant
R-Sq = 94.08% R-Sq(pred) = 98.097% R-Sq(adj) = 97.53%					

Table 5: Regression Coefficient for Ra

GRAPHICAL INFERENCES FOR MRR (mm³/min) FOR STEEL

Graphical implications of Taguchi for second response (Ra) have also been chalked out. Variation of Surface Finish with considered input factors, have been drawn in figure 5 Remember, as Surface Roughness (Ra) increases than its corresponding Surface Finish decreases and vice versa. Fig 5 (a) represents that there is an decrease in the Ra when the spindle speed raises from 700 rpm to 1400 rpm and there is further improvement in the quality of surface when cutting speed is raised from 1400 rpm to 2100 rpm. Where as in figure 5 (b) it has been shown that the value of surface roughness is lesser at lower feed rate. Similarly in figure 5 (c) it has been shown that the value of surface roughness is less at depth of cut is kept 0.4 mm. Similarly effect of two factors simultaneously on Ra has been captured by figure 6 .

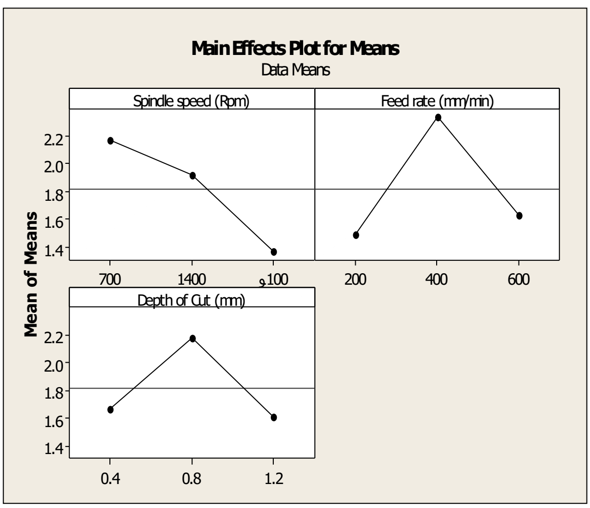

Figure 5:- Main Effects Plot for Ra(μm)

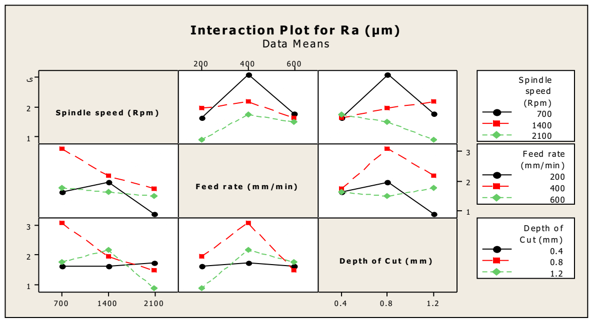

Fig.6 Two-Way Interaction Plot for MRR

8. CONCLUSION

The influences of depth of cut, spindle speed and feed rate on machined surface roughness and material removal rate in face milling operation have been studied. The experiment has been performed on Mild Steel and obtained data has been analyzed using Taguchi technique.It has been observed that, Taguchi's orthogonal array L 27 provides a large amount of information in a small amount of experimentation. All the three parameters are predominantly contributing to the responses and all have been considered. Optimum machining parameter combination has been found through Taguchi technique.Results of both techniques have been compared and optimum machining parameter combination setup has been suggested for minimizing surface roughness and for maximizing material removal rate. The surface roughness evaluated through Taguchi technique is 0.53 μm and through Estimated Regression Coefficients for Ra it is found that 97.53% surface roughness depends upon the Spindle speed, feed rate and depth of cut where as on the other hand the maximum Material removal rate found to be 10666.67 mm³/min through Estimated Regression Coefficients for MRR it is found that 94.86% material removal rate depends upon depends upon the Spindle speed, feed rate and depth of cut.

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