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ANALYSIS OF MACHINING PARAMETERS FOR THE OPTIMIZATION OF SURFACE ROUGHNESS OF STAINLESS STEEL AISI 202 IN CNC FACE MILLING PROCESS

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ABSTRACT

Face milling is a very common method for metal cutting and the finishing of machined parts. The stainless steel AISI 202 is used as work piece because of its widely use in various industries. Surface finish has been one of the most important considerations in determining the machinability of materials. The input machining parameters were being consider in this research are spindle speed, tool feed and depth of cut for the surface roughness.. The tool used for the face milling operation is carbide inserted face milling cutter. The Taguchi's L9 orthogonal array has been used to design the combinations of parameters for the experiments. The optimum levels of input parameters have been found by Taguchi's method are 2500 rpm spindle speed, 200 mm/min tool feed and 0.2 mm depth of cut. For the above results one more experiment was conducted to confirm these results and test results were found to agree with the theoretical conclusions.

KEYWORDS: Machining Parameters, Surface Roughness, Stainless Steel, CNC Face Milling

INTRODUCTION

CNC (Computer Numerical Control) milling machine is one of the common machine tools in machine industry. The face milling is an operation for producing plane or flat surfaces using a face milling cutter. It is used for finishing of machines parts. In face milling, the cutter is mounted on a spindle having an axis of rotation perpendicular to the work pieces surface and removes material in the manner. Face milling process is gaining popularity in industries in recent years due to the capability in improving machining performance, reducing cost while achieving reduced lead times, and higher productivity. However, the demand for high quality focuses attention on the surface condition and the quality of the product, especially the roughness of the machined surface because of its effect on product appearance, function, and reliability[1]. In addition, a good quality machined surface significantly improves fatigue strength, corrosion resistance, and creep life. Surface roughness is defined as a group of irregular waves in the surface, measured in micrometers (µm). With the more precise demand of modern engineering products, the control of surface texture has become more important. The surface roughness data obtained by measurement can be manipulated to determine the roughness parameter. There are many different roughness parameters in use, but R_a is by far the most common. The roughness average (R_a) is the mean arithmetic deviation of the profile from the mean line [2].

The surface roughness is mainly affected by different machining parameters such as rotation speed, feed rate, and cut depth. However, it is also affected by other uncontrolled variables such as the mechanical properties of the material, the type of the cutter and the vibration produced during the process. Surface finish has been one of the most important considerations in determining the machinability of materials [3]. Surface roughness and dimensional accuracy are the important factors required to predict machining performances of any machining operations. Stainless steel AISI 202 is a hard, cheap and corrosion resistant material which is widely used in industries but no literature could be revealed on its processing by face milling operation. SS 202 is most commonly used in chemical industries, marines, railway coaches, pressure vessels So it is proposed to analyze the surface roughness for stainless steel 202 using face milling operation.

EXPERIMENTAL SETUP & PROCEDURE

The experiments have been conducted on vertical CNC Milling Machine model VMC 640 of JYOTI available at Ambala college of Engg., Mithapur as shown in figure no. 1. Cutting speed, spindle speed, feed rate, depth of cut can be varied in the process. Surface roughness is effected by each of the these input parameters. The combination of parameters is depends upon the work-piece material.

Figure 1: Setup of Vertical CNC Milling Machine

Surface roughness was measured using the machine of company Mitutoyo; model Surfest SJ-301 available at MMU, Mullana. This machine uses the stylus method for measurement and measure surface roughness up to 100μm. . Surface roughness of each sample was measured at three different positions of each machined sample then their S/N ratio is calculated for further analysis as discussed later

Work Piece Material

The work piece material used was Stainless Steel AISI 202 in the cylindrical form having 49.8mm diameter and thickness 30 mm. The Stainless Steel 202 has a minimum of 17% chromium. This gives a very marked degree of general corrosion resistance with compared to other steels with lower percentage of chromium. The chemical composition and mechanical properties of SS 202 is shown in table no.1 and 2 respectively..

Table 1: Composition of Material SS 202

C (%)	Cr	Ni	Mn	Si	P	S	N
0.15	18	5	9	.85	.06	0.03	0.25

Table 2: Mechanical Properties of SS 202

Rockwell Hardness (HRB)	Tensile Strength (MPa)	Density (Kg/m^3)	Specific Heat (J/Kg.K)	Brinell Hardness (HB)
90	516	7800	503	241

Cutting Tool Material

The carbide inserted five flute face milling cutter was used for the present experiment. The five flute carbide inserted face milling cutter has give the better surface finish than the two, three and four flute carbide inserted cutting tool. The 50 mm of diameter carbide inserted five flute face milling cutter was used for present investigation.

METHODOLOGY

A scientific approach to plan the experiments is a necessity for efficient conduct of experiments. By the statistical design of experiments the process of planning the experiment is carried out, so that appropriate data will be collected and analyzed by statistical methods resulting in valid and objective conclusions. The methodology for this research is shown figure no. 2.

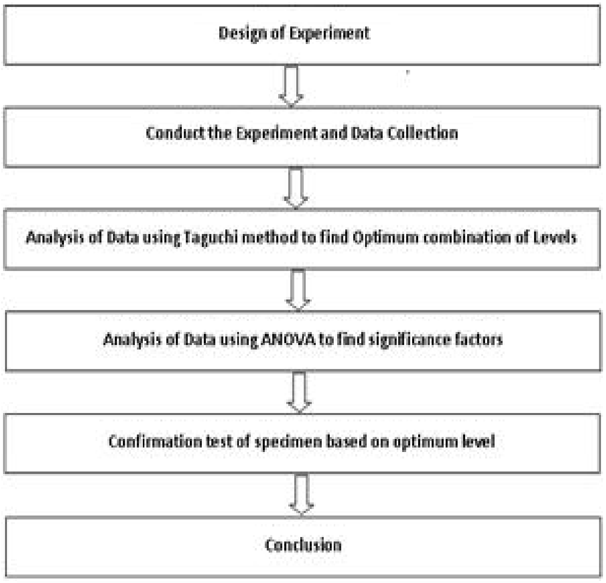

Figure 2: Flow Chart for Work

Taguchi's Method

Taguchi's Orthogonal Array (OA) provides a set of well balanced experiments (with less number of experimental runs), and Taguchi's signal-to-noise ratios (S/N), which are logarithmic functions of desired output; serve as objective functions in the optimization process. Taguchi method uses a statistical measure of performance called signal-to-noise ratio. The objective of using S/N ratio as a performance measurement is to develop products and processes insensitive to noise factors.

The S/N ratio indicates the degree of predictable performance of a product or process in the presence of noise factors. The S/N ratio takes both the mean and the variability into account. The S/N ratio is the ratio of the mean (Signal) to the standard deviation (Noise). The ratio depends on the quality characteristics of the product/process to be optimized. The standard S/N ratios generally used are as follows: - Nominal is Best (NB), Lower the Better (LB) and Higher the Better (HB). The optimal setting is the parameter combination, which has the highest S/N ratio.

A high value of S/N implies that signal is much higher than the random effects of noise factors. Process operation consistent with highest S/N always yields optimum quality with minimum variation [4].

The equation for calculating S/N ratios for smaller is better (LB),:

- Smaller the Better(SB)

$$S/N\ (\eta) = -10\log \frac{1}{n} \sum_{i=1}^{n} y_i^2$$

Where, n = number of measurements in a trial/row

y_i = the i^{th} measured value in a run/row

Analysis of Variance (ANOVA)

The analysis of variance is a statistical tool useful for determining the influence of any given input parameter from a series of experimental results by the design of experiments for machining process and it can be used to interpret experimental data. It is used in determining the percent contribution of each parameter against a stated level of confidence. Study of ANOVA table for a given analysis helps to determine which of the parameters need control . The one-way analysis of variance for the problem is given as shown in the table no.3. [5]

Table 3: One-Way ANOVA Method

Source of Variation	Sum of Squares	DOF	Mean Square	F Static
Between treatments	$SS(tr) = n\sum_{i=1}^{c}(\overline{Y}_i - \overline{Y})^2$	c - 1	$S_B^2 = \frac{SS(tr)}{c-1}$	$\frac{S_B^2}{S_W^2}$
Error (within groups)	$SSE = \sum_{i=1}^{c}\sum_{j=1}^{n}(Y_{ij} - \overline{Y}_i)^2$	n_T - c	$S_W^2 = \frac{SSE}{n_T - c}$	
Total Variation	$\mathbf{SST = \sum_{i=1}^{c}\sum_{j=1}^{n}(Y_{ij} - \overline{Y})^2}$	$\mathbf{n_T - 1}$		

Where, $\overline{Y}_i = \frac{1}{n}\sum_{j=1}^{n} Y_{ij}$, is the i^{th} sample means

$\overline{Y} = \frac{\sum_{i=1}^{c}\overline{Y_i}}{c}$ is the overall sample mean

SS(tr) = sum of squares between treatments or groups

SSE = error sum of squares

SST = total sum of squares

n_T = total number of trials

CALCULATIONS AND RESULTS

For the present experimental work the three process parameters each at three levels have been decided. Three parameters with three levels each are selected for experimentation as shown in table no 4. The degree of freedom (DOF) of a three level parameter is 2 (number of levels-1), hence total DOF for the experiment is 6.

Table 4: Input Parameters and their Levels

Controllable Factors	Level 1	Level 2	Level 3	Output Parameter
Spindle Speed (rpm)	500	1500	2500	Surface Roughness (μm)
Tool Feed (mm/min)	100	200	250	
Depth of Cut (mm)	0.3	0.2	0.1	

Table 5: Experimental Result and S/N Ratio

Exp. No.	Spindle Speed	Tool Feed	Depth of Cut	Surface Roughness in μm			S/N Ratio
				R_1	R_2	R_3	
1	500	100	0.3	0.56	0.41	0.60	5.6799
2	500	200	0.2	0.32	0.29	0.18	11.7005
3	500	250	0.1	0.57	0.33	0.54	6.3752
4	1500	100	0.2	0.28	0.25	0.21	12.0412
5	1500	200	0.1	0.33	0.27	0.36	9.8970
6	1500	250	0.3	0.75	0.64	0.71	3.0980
7	2500	100	0.1	0.31	0.33	0.38	9.3704
8	2500	200	0.3	0.20	0.27	0.17	13.5556
9	2500	250	0.2	0.46	0.60	0.56	5.3521

So L9 orthogonal array was taken. The experimental result of surface roughness and their calculated S/N ratio is shown in table 5. The average effect response table for the raw data and S/N ratio shown in table 6 and 7 respectively.

Table 6: Average Effect Response for Raw Data

Level	Spindle Speed(A)	Tool Feed(B)	Depth of Cut(C)
1	0.42	0.37	0.38
2	0.4283	0.2633	0.35
3	0.3633	0.5733	0.4767
Delta(Δ)	0.06	0.31	0.1267
Rank	**3**	**1**	**2**

Table 7: Average Effect Response for S/N Ratio

Level	Spindle Speed(A)	Tool Feed(B)	Depth of Cut(C)
1	7.919	9.031	8.548
2	8.345	11.718	9.698
3	9.426	4.942	7.445
Delta(Δ)	1.508	6.776	2.253
Rank	**3**	**1**	**2**

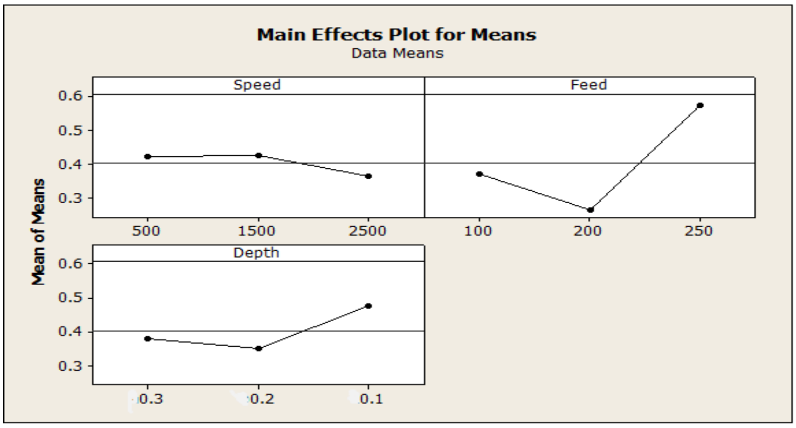

Figure 3: Main Effect Plot of Means for SR

Table 8: Analysis of Variance for SR

Source of Variation	Sum of Squares	DOF	Mean Square	F
Spindle speed	0.006858	2	0.003429	0.19
Tool feed	0.148236	2	0.074118	4.11
Depth of cut	0.027816	2	0.013908	0.77
Error	0.036068	2	0.018034	
Total	**0.218978**	**8**		

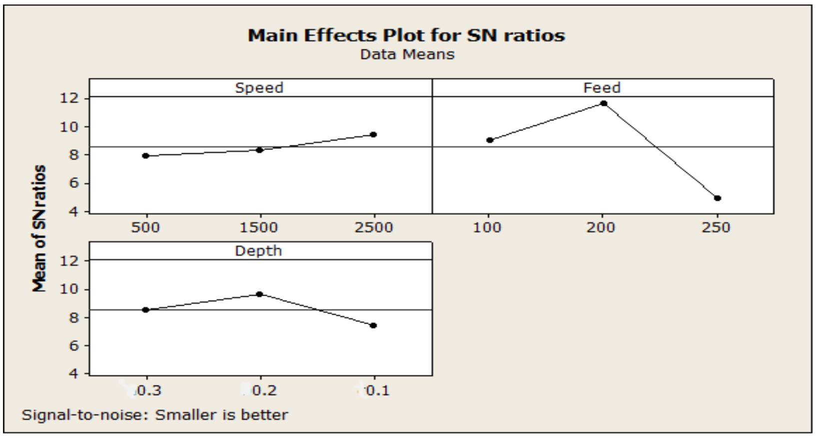

Figure 4: Main Effect Plot of S/N Ratio for SR

ANALYSIS OF RESULTS

After raw data were collected, average effect response values for raw data (Table no. 6) and S/N response ratios (Table no. 6) are calculated. The Delta (Δ) as shown in tables is the difference of maximum and minimum values of each responses. The Tool feed(B), Depth of cut(C), Spindle Speed(A) are assigned as rank 1, 2 and 3 respectively according to the largest value of delta. Rank 3 and Rank 1 means lowest and highest contribution factor for the SR respectively.

From the tables on the basis of rank shown, it has been analyzed that the parameter tool feed is the most influencing factor which affect the surface roughness of material. This parameter tool feed affect the surface roughness with more difference at different level than other two parameters. According to ANOVA The tabulated value of F ratio at 5% level of significance is given by:

$f_{(2,2;0.05)} = 19$

Since the tabulated value of F ratio is 19 and observed values of parameters e.g. spindle speed, tool feed, depth of cut are 0.19, 4.11 and 0.77 respectively less than the tabulated value, the responses are insignificant. So for this case ANOVA table is not supporting

Predict Optimum Performance & Confirmation Test

The graphs for average effect response for the mean and S/N ratio as shown in figure no. 4 and 4 respectively. Machining parameter settings with the highest S/N ratio always yield the optimum quality with minimum variance. For example, in figure no. 4, level three for spindle speed (A3=2500 rpm) has the highest S/N ratio value, which indicated that the machining performance at such level produced minimum variation of the surface roughness. In addition, the lower surface roughness value had a better machining performance. Furthermore, level three of spindle speed (A3 = 2500 rpm) has indicated the optimum situation in terms of mean value. Similarly, the level two of tool feed (B2=200 mm/min) and the level two of depth of cut. (C2=0.2 mm) have also indicated the optimum situation in terms of S/N ratio and mean value. The optimum surface roughness performance could be predicted using the following Taguchi equation:

Predicted mean = $\overline{R_a} + \sum_{i=1}^{n}[\mathrm{R_o} - \overline{\mathrm{R_a}}]$

Where, $\overline{R_a}$ = total mean of surface roughness

R_o = mean of surface roughness at optimum level

Predicted mean = 0.402 + (0.3633-0.402) + (0.2633-0.402) + (0.35-0.402) = 0.17 µm

After performing experiment again as per given optimum levels following result obtained:

Table 9: Experimental and Optimal Result of Surface Roughness

Predicted Value at A3 B2 C2	Experimental Result at A3 B2 C2	Percentage Change
0.17µm	0.20µm	0.03%

So it found that there is 0.03% improvement in surface roughness of the optimum parameters.

Comparison of Present Work with Other Research Works

The comparison of present work with other work is shown in table no.10. After comparing with other research papers it has been concluded that the face milling operation gives the better surface finish for SS 202 as compared to other operations and machines except aluminum alloy.

Table 10: Comparison of Present Work with Others

Conditions	Present Work	Rohit Garg [6]	M. Kaladhar [7]	Nikul D. Patel [8]	P.G. Benardos [9]
Cutting speed	2500 rpm	358.8 rpm	200 m/min	24.976 m/min	3977 rpm
Feed rate	200 mm/min	1148 mm/min	0.15 mm/rev	5.341 mm/rev	1272 mm/min
Depth of cut	0.2 mm	0.3 mm	0.25 mm	1.0 mm	0.25 mm
Work material	SS-202	H13 die steel	SS-202	SS-202	Aluminum alloy
Method of analysis	Taguchi & ANOVA	Taguchi method	DOE & ANOVA	Taguchi method	Taguchi & Neural Network
Machine used	VMC-640	VMC-850	CNC Lathe	Peeling machine	CNC vertical milling machine
Process	Face milling	End milling	Turning	Bar peeling	Face milling
Tool used	Face mill(50mm dia)	End mill (12.7mm dia)	CVD coated cemented carbide	Carbide inserts tool	Face mill(40mm dia)
Optimum surface roughness	0.20 µm	0.96 µm	0.70 µm	3.67 µm	0.18 µm

CONCLUSIONS

In this study the optimal machining condition for face milling operation of stainless steel 202 is determined by varying machining parameters through the Taguchi technique. The tool feed most influencing factor and then depth of cut and the last is spindle speed. The surface finish increases with the higher value of spindle speed. The tool feed 200mm/min shows the better surface finish while the tool feed 250mm/min shows the worst surface finish as compare to 100mm/min and 200mm/min tool feed. For higher value of spindle speed (2500 rpm) the surface finish is best. At depth of cut 0.2 mm, the surface finish is highest. It can be observed that the difference between the value of the minimum predicted surface roughness and the actual surface roughness values from confirmation experiments is 0.03µm. The better surface finish for SS 202 has been found as compared to other materials for different methods.

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