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Optimization the Parameters of SS 202 on Vertical Milling Machine

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Abstract— In the last few years the development of new materials show deep growth but the major problem is its machining. So it is necessary adopt new machining methods. Face milling is very common method for finishing of new materials and machined materials. For increasing productivity, it is necessary that machining should be optimized to get maximum profit. In the optimization of milling, process parameters are (spindle speed, tool feed and depth of cut) affects the output (Material Removal Rate and Surface Roughness).The present work is aimed at developing an efficient method for determination of best combination of these machine process parameters which could maximize the material removal rate and minimize the surface roughness.

Key words: MRR, Cutting Phenomena

I. INTRODUCTION

Milling is a process of producing flat and complex shapes with the use of multi-tooth cutting tool, which is called a milling cutter and the cutting edges are called teeth. The axis of rotation of the cutting tool is perpendicular to the direction of feed, either parallel or perpendicular to the machined surface. Milling is a fundamental machining operation. Face milling is the most common metal removal operation encountered. Material removal rate (MRR) and surface roughness (SR) is an important control factor of machining operation and the control of machining rate is also critical for production planners. The experiment is conducted on SS 202 and the processing of the job is done by carbide face-millingtool.

A. *Input Parameters of Milling:*

In the milling process there are mainly four input parameters which responsible for output like surface finis and material removal rate they are:

1) *Machine Parameter:*

Machine parameters are further categorized into feed rate, depth of cut, cutting speed, cutting fluid etc. In the machining of any part we change this parameter a no. of time to find the desired shape. Thus these are the most important parameters to get the better output.

2) *Work Piece:*

Work piece properties affect the output properties like surface finish, material removal rate, power consumption etc. Work piece properties basically consider work piece shape, its material and hardness of the work piece.

3) *Cutting Phenomena:*

Cutting phenomena basically counts the vibration during process, chip formation and friction in cutting zone. The effect of vibration is easily seen on the machined surface as irregularities on the machined surface. These irregularities decrease the surface finish.

4) *Cutting Tool Properties:*

Cutting tool properties consider the several properties like nose radius, tool material, tool wear and tool shape etc. Tool shape considers the tool diameter, length, no. of flutes or cutting edges etc. Tool shape affects the MRR to a great extent

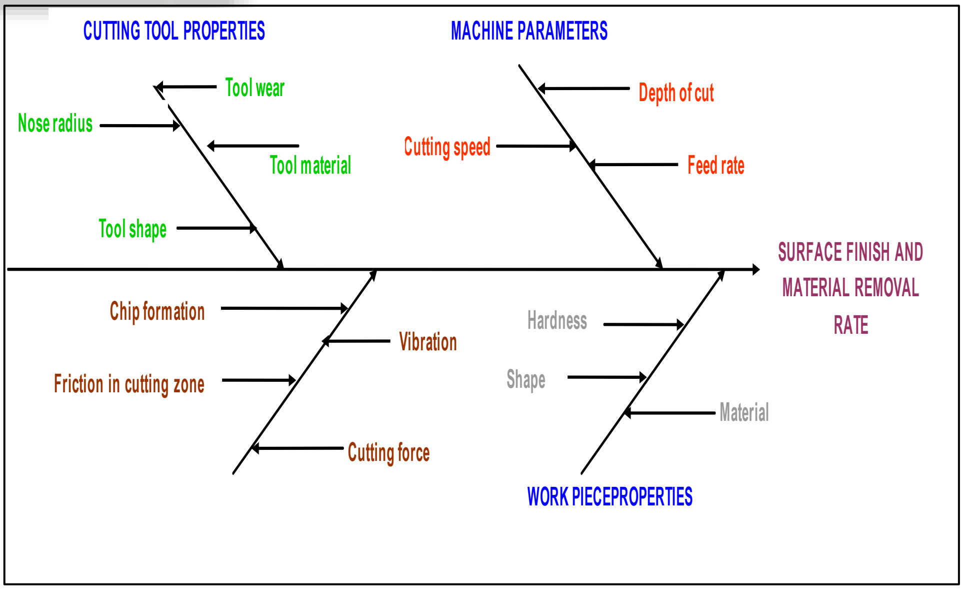

Fig. 1.1: Cause and Effect Diagram

B. *Output Characteristics of Milling:*

There are many output characteristics but surface finish and material removal rate are most important in production and quality.

1) Surface Roughness (SR): Roughness is a measure of the texture of a surface.
2) Material Removal Rate (MRR): Material removal rate is the volume of material removed per unit time from the work piece surface.

II. LITERATURE REVIEW

Qinglong et al. [1] investigated hard milling of 30Cr3 using a PVD-AlTiN coated cemented carbide tool with regard to cutting forces, surface roughness, chip formation and tool wear, respectively. Hard milling is an efficient way in machining high strength steels. The experimental results indicated that the increase of cutting speed leads to direct reduction of cutting forces and improvement of surface finish, while both feed rate and depth of cut have negative effect on surface finish.

Thakkar and Patel [2] investigated the process parameters like speed, feed, and depth of cut for optimization of surface roughness. All experiments were conduct on CNC turning machine on SS410 material. In the present work, Design of Experiment (DOE) with full factorial design had been explored to produce 27 specimens on SS410 by straight turning operation. Material removal rate (MRR) will be calculated from MRR equation and software available for it and then compare it. Collected data related to surface roughness have been utilized for optimization.

Prajapati and Patel [3] studied the performance of SS 316 austenite steel material in turning process to minimize surface roughness and maximize material removal rate. The full factorial method and analysis of variance are employed to study the performance characteristics in CNC turning operation. Three machining parameters are chosen as process parameters: Cutting Speed, Feed rate and Depth of cut. The experimentation plan is designed using design of experiment, L27 orthogonal array and Minitab-16 statistical software is used. Optimal values of process parameters for desired performance characteristics are obtained by analysis of variance (ANOVA).

Yadav et al. [4] investigated machining performance of Medium Carbon Steel AISI 1045 in turning for surface roughness in dry conditions. In this study, the effect and optimization of machining parameters (cutting speed, feed rate and depth of cut) on surface roughness is investigated. An L27 orthogonal array, analysis of variance (ANOVA) and the signal-to-noise (S/N) ratio were.

Joshi et al. [5] studied material removal rate of aluminium cast alloy on CNC Vertical End Milling Machine. CNC end milling is a unique adaption of the conventional milling process which uses an end mill tool for the machining process. The effects of various parameters of end milling process like spindle speed, depth of cut, feed rate have been investigated to reveal their Impact on Material Removal Rate using Taguchi Methodology. Experimental plan is performed by a Standard Orthogonal Array. The results of analysis of variance (ANOVA) indicate that the proposed mathematical model can be adequately describing the performance within the limit of factors being studied. The optimal set of process parameters has also been predicted to maximize the MRR.

Reddy et al. [6] investigated surface roughness of Pre-hardened steel using Response surface methodology and genetic algorithm. To achieve the minimum surface roughness optimal conditions are determined. The experiments were conducted using Taguchi's L50 orthogonal array in the design of experiments by considering the machining parameters such as Nose radius, Cutting speed, feed, axial depth of cut and radial depth of cut. A predictive response surface model for surface roughness is developed using RSM. The response surface model is interfaced with the genetic algorithm to find the optimum machining parameter values.

Sun and Guo [7] studied performance of titanium Ti–6Al–4V on End milling.In this study, a series of end milling experiments were conducted to comprehensively characterize surface integrity at various milling conditions. The experimental results have shown that the milled surface shows the anisotropic nature with the range of surface roughness values. Surface roughness value increases with feed and radial depth-of-cut, but has much less variation in the cutting speed range.

BAJIC et al. [8] studied the cutting parameters on face milling for surface roughness. Cutting speed, feed rate and depth of cut had been taken into consideration. A series of experiments have been carried out in accordance with a design of experiment (DOE). In order to obtain mathematical models that are able to predict surface roughness two different modeling approaches, namely regression analysis and neural networks, had been applied to experimentally determined data. Obtained results have been compared and neural network model gives better explanation of the observed physical system. Optimal cutting parameters have been found using simplex optimization algorithm.

Routara et al. [9] investigated machining parameters spindle speed, depth of cut and feed rate on CNC end milling. In this study, experiment was conducted for three different work piece materials (6061-T4 aluminium, AISI 1040 steel and medium leaded brass UNS C34000. An attempt had also been made to obtain optimum cutting conditions with respect to each of the five roughness parameters with the help of response optimization technique.

Zhang et al. [10] studied Taguchi design application to optimize surface quality in a CNC face milling operation for aluminium. This study included feed rate, spindle speed and depth of cut as control factors. An orthogonal array of L9 was used; ANOVA analyses were carried out to identify the significant factors affecting surface roughness, and the optimal cutting combination was determined by seeking the best surface roughness (response) and signal-to-noise ratio.

III. EXPERIMENT AND DATA COLLECTION

In this experiment, the controllable factors are spindle speed, feed rate, and depth of cut, which are selected because they can potentially affect surface roughness performance and material removal rate in end-milling operations. Since these factors are controllable in the machining process, they are considered ascontrollable factors in the experiment. Table 1.3 listed all the Taguchi design parameters and levels.

1) Three level of spindle speed have been used.
2) Three level of tool feed have been used.
3) Three level of depth of cut have been used.

A. Work Piece:

The experiment was performed on CNC vertical milling machine. The work piece material was SS 202 in cylindrical form of diameter 40 mm and 140 mm length. Five pieces was cut on power hacksaw and after facing of that pieces nine experiments were performed on CNC vertical milling machine (VMC-640). Carbide Face milling cutter (with diameter 12 mm) was used for this experiment.The chemical composition of SS 202 which was tested at CITCO (Chandigarh Industrial and Tourism Development Corporation Ltd.), Chandigarh is shown in table 1.1. The mechanical, physical and electrical properties of SS 202 as shown in table 1.2.Applications of SS 202 in Restaurant equipment, cooking utensils, Sinks, Architectural applications such as windows and doors, Railway cars, Hose clamps.

Constituent	**% Composition**
C	0.1152 %
Cr	14.60 %
Mn	5.216 %
Si	0.5559 %
P	0.04565 %
S	0.01409 %
Cu	0.0526 %
V	0.0357 %
Mo	0.2111 %
Ni	2.73 %

Table 1.1: Chemical Composition of SS410

Tensile Strength (MPa)	515
Yield Strength (MPa)	275
Hardness(HB)	240
Density (kg/m3)	7800
Elastic Modulus(GPa)	207
Specific Heat(J/Kg K) 0-100^0 C	500
Thermal Conductivity(W/m.K) at 100^0 C	16.2
Electrical Resistivity (10^{-9}nΩ.m) at 25^0 C	690

Table 1.2: Mechanical, Physical and Electrical Properties

Process parameters	**Level 1**	**Level 2**	**Level 3**
Spindle speed	1000	2000	3000
Tool feed	200	400	600
Depth of cut	0.1	0.2	0.3

Table 1.3: Selected Factors and Levels

Run	**Spindle speed(rpm)**	**Tool Feed(mm/rev)**	**Depth of cut(mm)**	**Surface roughness in µm**		**Surface roughness mean**	**S/N ratio**
				SR 1	**SR 2**		
1	1000	200	0.1	0.9777	1.124	1.05085	-0.43081
2	1000	400	0.2	1.179	1.312	1.24550	-1.90687
3	1000	600	0.3	1.954	1.73	1.84200	-5.30579
4	2000	200	0.2	0.553	0.749	0.65100	3.72838
5	2000	400	0.3	1.837	1.824	1.83050	-5.25139
6	2000	600	0.1	1.094	1.315	1.20450	-1.61614
7	3000	200	0.	0.912	0.766	0.83900	1.52476
8	3000	400	0.1	0.964	0.893	0.92850	0.64436
9	3000	600	0.2	1.029	0.957	0.99300	0.06102

Table 1.2: L9 Orthogonal Array for SR

Run	**Spindle speed (rpm)**	**Tool Feed (mm/rev)**	**Depth of cut (mm)**	**Material removal rate (g/sec)**		**MRR mean**	**S/N ratio**
				MR R1	**MR R2**		
1	1000	200	0.1	0.24	0.2608	0.2504	-12.0273
2	1000	400	0.2	0.6	0.6666	0.6333	-3.9678
3	1000	600	0.3	1.5	1.398	1.449	3.2214
4	2000	200	0.2	0.32	0.3345	0.32725	-9.7024
5	2000	400	0.3	0.8888	0.9846	0.9367	-0.5680
6	2000	600	0.1	0.3076	0.3184	0.313	-10.0891
7	3000	200	0.3	0.3702	0.3976	0.3839	-8.3156
8	3000	400	0.1	0.25	0.2984	0.2742	-11.2387
9	3000	600	0.2	0.8332	0.7142	0.7737	-2.2285

Table 1.3: L9 Orthogonal Array for Material Removal Rate

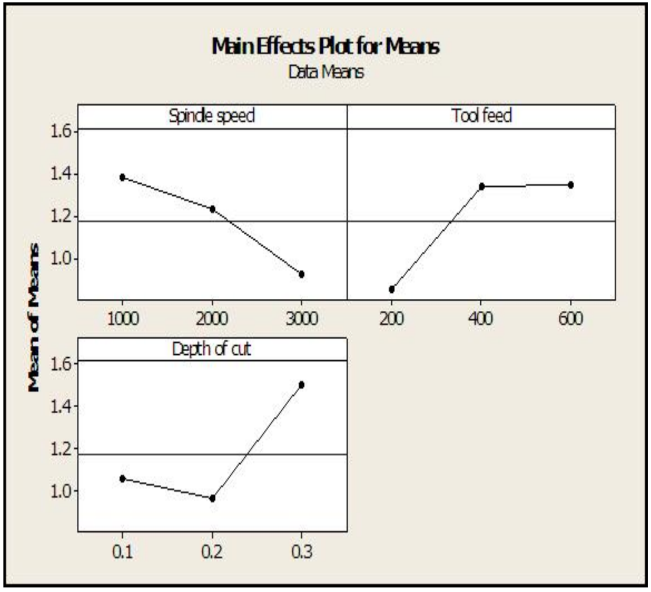

Fig. 1.2: Response Graph of Three Machining Parameters for Mean for SR

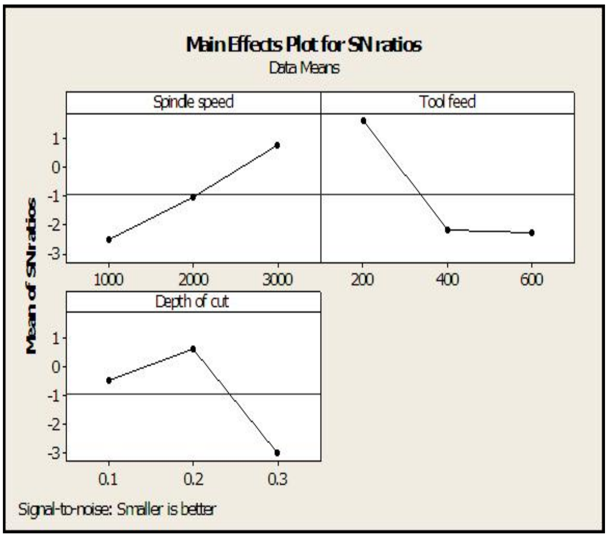

Fig. 1.3: Response Graph of Three Machining Parameters for S/N Ratio for SR

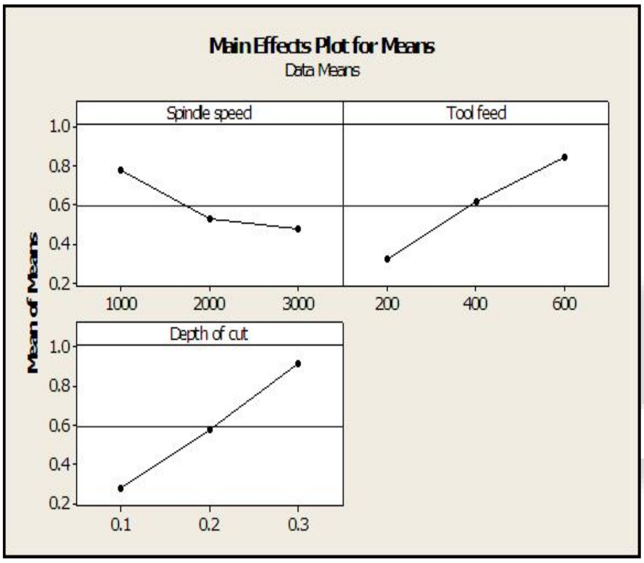

Fig. 1.4: Response Graph of Three Machining Parameters for Mean for MRR

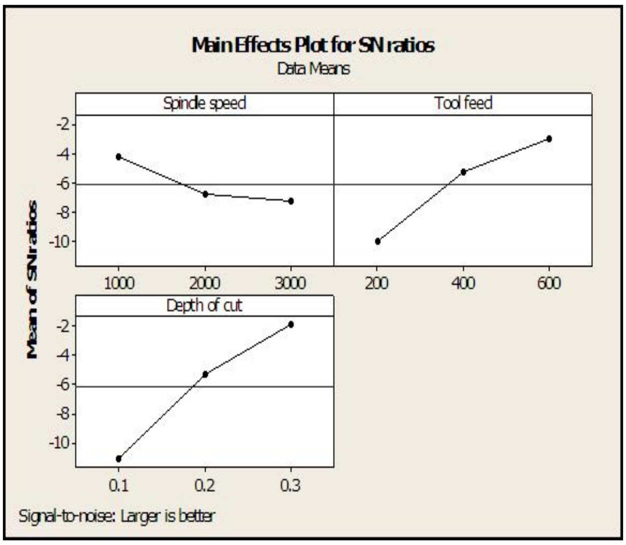

Fig. 1.5: Response Graph of Three Machining Parameters for S/N Ratio for MRR

Figure 1.2 shows three graphs, each of which contains a curve representing the mean and figure1.3 a curve representing the S/N ratio. The S/N ratio indicates the degree of the predictable performance of a product or process in the presence of noise factors. Machining parameter setting with the highest S/N ratio always yield the optimum quality with minimum variance. The level that has a higher value determines the optimum level of each factor. For example, in figure 1.3, level three for spindle speed (A3=3000 rpm) has the highest S/N ratio value, which indicated that machining performance at such level produced minimum variation of surface roughness. In addition, the lower surface roughness value had a better machining performance. Furthermore, level one of spindle speed (A3=3000 rpm) has indicated the optimum situation in terms of mean value. Similarly, the level one of tool feed (B1=200 mm/rev) 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.In the experimental analysis, main effect plot of S/N ratio is used for estimating the S/N ratio of MRR with optimal design condition. As shown in figure1.5 level one for Spindle speed (A1=1000 rpm) has highest value and level three of tool feed (B3=600 mm/rev) and the level three of depth of cut (C3= 0.3 mm) have also indicated the optimum situation.

Level	Spindle speed	Tool feed	Depth of cut
1	1.3795	0.8469	1.0613
2	1.2287	1.3348	1.0331
3	0.9202	1.3465	1.5038
Delta (Δ)	0.4593	0.4996	0.4707
Rank	3	1	2

Table 1.4: Average Effect Response Table for SR

Level	Spindle speed	Tool feed	Depth of cut
1	0.7776	0.3205	0.2792
2	0.5257	0.6147	0.5781
3	0.4773	0.8452	0.9232
Delta (Δ)	0.3003	0.5247	0.6440
Rank	3	2	1

Table 1.5: Average Effect Response Table for MRR

From the table 1.4, it has been analyzed that the parameter tool feed is the most significant factor which affects the surface roughness. From the table 1.5, it has been analyzed that the parameter depth of cut is the most significant factor which affects the material removal rates.

Analysis of Variance: The purpose of analysis of variance (ANOVA) is to determine which parameters significantly affect the quality characteristic. The analysis of variance is to identify the set of all independent variable (factors) that can potentially affect the value of response variable. The response table for the surface roughness and MRR is as shown below.

Source	DF	SS	MS	F	% contribution
Spindle speed	2	0.1560	0.07799	1.52	12.02 %
Tool feed	2	0.4150	0.20751	4.04	31.99 %
Depth of cut	2	0.6232	0.31159	6.07	48.05 %
Residual Error	2	0.1027	0.05136		7.91 %
Total	8	1.2969			100 %

Table 1.6: Analysis of Variance Tables for MRR

Source	**DF**	**SS**	**MS**	**F**	**% contribution**
Spindle speed	2	0.32885	0.16442	5.24	23.87 %
Tool feed	2	0.49780	0.24386	7.93	36.14 %
Depth of cut	2	0.48772	0.24890	7.77	35.14 %
Residual Error	2	0.06281	0.03140		4.56 %
Total	8	1.37717			100 %

Table 1.7: Analysis of Variance Table for SR

The results are analyzed using ANOVA for identified the significant factor affecting the performance measure. The ANOVA for MRR& SR is taken at 95 % of confidence level. The principal of F test is that larger the F values for a particular parameter, greater the effect on performance characteristics due to change in process parameters. Above tables show the significant factor and also shows percentage contribution.

IV. RESULT AND ANALYSIS

1) In face milling, use of high spindle speed (3000 rpm), low feed rate (200mm/rev) and depth of cut (0.2mm) are optimized parameters to obtained better surface finish for the specific test range in a SS 202 material.
2) The predicted optimal value of SR with the help of MINITAB is 0.378094 µm.
3) In face milling, use of lowest spindle speed (1000 rpm), high feed rate (600mm/rev) and high depth of cut (0.3mm) are optimized parameters to obtained highest MRR for the specific test range in a SS 202 material.
4) The predicted optimal value of MRR with the help of MINITAB is 1.35901 g /sec.
5) Taguchi’s robust design method is suitable to analyze the metal cutting problem as described in the present work.

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