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# Study and Investigation on Effects of Cutting Parameters on Output in CNC Milling Process Using L9 Orthogonal Array

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## ABSTRACT

*CNC milling is one of the most commonly used in industry and machine shops today for machining parts to precise sizes and shapes. The objective of this experimental investigation is to conduct research of machining parameters of the machine impact on product quality and productivity of the process. For the analysis input parameters like feed rate, spindle speed and depth of cut selected as a control factors in Taguchi technique of response variable optimization with keeping operating chamber temperature and the usage of different tool inserts constant. And the product quality in terms of Surface roughness and productivity as material removal rate is measured. An orthogonal array of L9 was used .In this paper signal-to-noise ratio method is applied to find optimum process parameters for finishing operation of Cast iron with the help of CNC milling machine and Carbide tool used. The signal-to-noise ratio applied to find optimum process parameter for CNC finishing machining .A L9 orthogonal array and analysis of variance (ANOVA) are applied to study the performance characteristics of machining parameter (spindle speed, feed, depth, width) high material removal rate (MRR) .The surface finishing and material removal rate have been identified as quality attributes and assumed to be directly related to productivity improvement. Results obtained by taguchi method and signal-to-noise ratio match closely with (ANOVA) and the feed is most effective factor for MRR.*

**Keywords:** *CNC milling machine, material removal rate (MRR), L9 orthogonal array, and ANOVA, S/N Ratio. Mean.*

## 1.0 INTRODUCTION

Taguchi's parameter design offers a procedural approach for utilization of various parameters with respect to performance quality and cost. The quality is most important factor to improve productivity of the any industries. The quality and cost are basic requirement to the customer and satisfy the customer demand. For this purpose quality of a product and productivity should be high and cost should be low. Design optimization for quality was carried out and single to noise ratio and analysis of variance (ANOVA) were employed using experiment result to confirm effectiveness of this approach. The signal to noise ratio in Taguchi

methodology have been widely used in engineering design to find the optimal parameter for material removal rate and surface roughness in finishing operation based experimental results done on Cast iron work piece and high speed steel tool. The personnel industry as well as in research and development is required maintain surface roughness and MRR. The taguchi optimization methodologies to optimize the finishing parameter in CNC milling machining use mild steel and tool is high speed steel .Authors analysed the data using ANOVA with the help of commercial software package minitab-16.A series of experiment based on the Taguchi L9 orthogonal array is utilized for experimental planning for CNC milling.

## 1.1 Literature review

Ali R. Yildiz[1] introduced a new optimization algorithm, called the cuckoo search algorithm (CS) algorithm for solving manufacturing optimization problems. Author found significant improvement with the Cukoo Search compared to the feasible direction method, ant colony algorithm, immune algorithm, hybrid particle swarm, hybrid immune algorithm, genetic algorithm and handbook recommendations. Prof.V.M.Prajapati et al [2] in 2013 suggested CNC milling is one of the most commonly used in industry and machine shops today for machining parts to precise sizes and shapes. Amit joshi et al [3] in 2013 give survey and says that CNC End milling is a unique adaption of the conventional milling process which uses an end mill tool for the machining process. During the End milling process, the material is removed by the end mill cutter. 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 surface finish using Taguchi Methodology. Piyushpandey* et al [4] in 2013 conducted an experiment was conducted to perform the parametric optimization of CNC end milling machine tool in varying condition. The tool used for experiment was of Solid Carbide and the Mild Steel work piece was used during experiment. The experiment has been taken place efficiently and completes its all objective of optimization. The practical result can be used in industry to get the desirable Surface Roughness and Material Removal Rate for the work piece by using suitable parameter combination.

## 2. EXPERIMENTAL PROCESSES

### 2.1 Work piece Material

Finishing operation will be performed on Cast iron work piece. Experiments were performed using a CNC vertical Milling machine. A block of Cast iron of size 95 mm×95 mm×95mm was taken.

### 2.2 Plan of experiment:-

The plan of experiment is taken a block of Cast iron of size 95 mm×95 mm×95mm was taken.

In this finishing operation are performed with 20 mm diameter of tool. The experiments were conducted according to taguchi orthogonal array. Which helps in reducing the number of experiment. In this paper four parameter and three levels considered for experimental runs. Optimization for quality was carried out with signal to noise ratio and analysis of variance (ANOVA).

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## 2.3 Machine specification.

**Table 1: Shows Machine specification**

| | |
|---|---|
| Manufacturer | Surya VF 30 CNC VS |
| Table size | 1060X 315 mm |
| Maximum load on table | 300 kg |
| Maximum traverse travel (X axis) | 800 mm |
| Maximum traverse travel (Y axis) | 350 mm |
| Maximum traverse travel (Z axis) | 380 mm |
| Maximum power | 16 Kva |
| Spindle Speed | 50-6000 rpm |
| Maximum Rapid Speed | 5000 mm/min |

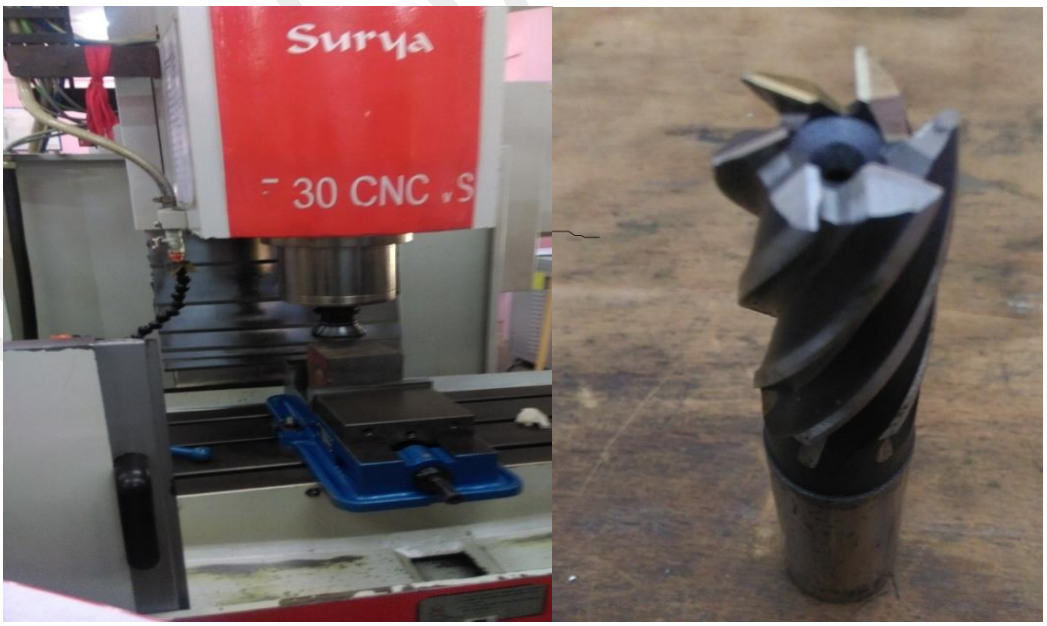


Figure: 1 Image of CNC milling machine and the carbide tool used.

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## 3. DESIGN OF EXPERIMENT AND DATA ANALYSIS

### 3.1. Design of Experiment

The experimental layout for the machining parameters using the $L_9$ orthogonal array (OA) and Signal to noise ratio. The machine was used for the finishing operation in this study. The surface and MRR are two essential part of a product in any drilling machining operation the theoretical surface roughness is generally dependent on many parameters such as the tool geometry, tool material and work piece material. This array having a four control parameters and three levels as shown in Table 2.This method, more essentials all of the observed values are calculated based on 'the Higher the better' and 'the smaller the better'. In the present study spindle speed (N, rpm) Feed rate (f, mm/min.) depth of cut (D, mm) and width of cut (W, mm) have been selected as design factor. While other parameter have been assumed to be constant over the Experimental domain. This Experiment focuses the observed values of MRR was set to maximum, intermediate and minimum respectively. Each experimental trial was performed with three simple replications at each set value. Next, Signal to noise ratio is used to optimize the observed values.

***Table 2: Design scheme of experiment of Parameters and levels***

| Control parameters | Level | | | Observed Value |
|---|---|---|---|---|
| | 1 | 2 | 3 | |
| | Minimum | Intermediate | Maximum | |
| Spindle Speed's(rpm)<br>Feed Rate (mm/min.)<br>Depth of cut (mm)<br>Width of cut (mm) | 200<br>200<br>.01<br>.1 | 1000<br>1000<br>.05<br>.2 | 2000<br>2000<br>.1<br>.4 | Material removal rate (g/min) |

### 3.2 Methodology

### SIGNAL TO NOISE RATIO CALCULATION

S/N characteristics formulated for three different categories are as follows:

Larger is Best Characteristic:

Data sequence for MRR (Material Removal Rate), which are higher-the-better performance characteristic are pre-processed as per Eq.1

$$S/N = -10 \log ((1/n) ((1/y^2)) \quad \text{.....}$$

Nominal and Smaller are Best Characteristics

Data sequences for SR, which are lower-the-better performance characteristic, are pre-processed as per Eq.2 &3

$S/N = -10 \log (y/s^2 y)$.....2

$S/N = -10 \log ((1/n) (\sum(y^2))$.....3

Where $\hat{y}$ is average of observed data y, $sy^2$ is variance of y, and n is number of observation.

### 3.3 Data Analysis

The machining performance (ANOVA-rank factor) for each experiment of the L9 can be calculated by taking the observed values of the MRR as an example from table 3. The taugchi analysis parameter for spindle speed (A) feed (B) depth of cut(C) and width of cut (D).

*Table 3: Experimental data for L9 Orthogonal array***.**

| No. of Trial | Control Parameter(level) | | | | MRR (g/min.) | | |
|---|---|---|---|---|---|---|---|
| | Spindle Speed(S) | Feed (F) | Depth of Cut(D) | Width of Cut(W) | 1 | 2 | 3 |
| 1 | 200 | 200 | 0.01 | 0.1 | 0.98 | 0.96 | 0.96 |
| 2 | 200 | 1000 | 0.05 | 0.2 | 0.93 | 0.97 | 0.96 |
| 3 | 200 | 2000 | 0.1 | 0.4 | 0.86 | 0.87 | 0.90 |
| 4 | 1000 | 200 | 0.05 | 0.4 | 0.89 | 0.90 | 0.91 |
| 5 | 1000 | 1000 | 0.1 | 0.1 | 0.90 | 0.92 | 0.90 |
| 6 | 1000 | 2000 | 0.01 | 0.2 | 0.83 | 0.86 | 0.85 |
| 7 | 2000 | 200 | 0.1 | 0.2 | 0.85 | 0.83 | 0.83 |
| 8 | 2000 | 1000 | 0.01 | 0.4 | 0.97 | 0.95 | 0.93 |
| 9 | 2000 | 2000 | 0.05 | 0.1 | 0.90 | 0.91 | 0.88 |

*Table 4: S/N Ratio and mean for MRR (Larger is Better)*

| No. of Trial | 1 | 2 | 3 | Average response value | SNRA | MEAN |
|---|---|---|---|---|---|---|
| 1 | 0.98 | 0.96 | 0.96 | 0.9667 | -0.29417 | 0.9667 |
| 2 | 0.93 | 0.97 | 0.96 | 0.9533 | -0.41541 | 0.9533 |
| 3 | 0.86 | 0.87 | 0.90 | 0.8767 | -1.14298 | 0.8767 |
| 4 | 0.89 | 0.90 | 0.91 | 0.9000 | -0.91515 | 0.9000 |
| 5 | 0.90 | 0.92 | 0.90 | 0.9067 | -0.85073 | 0.9067 |
| 6 | 0.83 | 0.86 | 0.85 | 0.8467 | -1.44541 | 0.8467 |
| 7 | 0.85 | 0.83 | 0.83 | 0.8367 | -1.54860 | 0.8367 |
| 8 | 0.97 | 0.95 | 0.93 | 0.9500 | -0.44553 | 0.9500 |
| 9 | 0.90 | 0.91 | 0.88 | 0.8967 | -0.94706 | 0.8967 |

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# 4 TAGUCHI DESIGN: MINITAB ANALYSIS

## 4.1 Taguchi Analysis: response versus A, B, C, D

*Table 5: Response for Signal to Noise Ratios (Larger is better)*

| LEVEL | A | B | C | D |
|---|---|---|---|---|
| 1 | -0.6175 | -0.9193 | -0.7284 | -0.6973 |
| 2 | -1.0704 | -0.5706 | -0.7592 | -1.1365 |
| 3 | -0.9804 | -1.1785 | -1.1808 | -0.8346 |
| Delta | 0.4529 | 0.6079 | 0.4524 | 0.4392 |
| Rank | 2 | 1 | 3 | 4 |

*Table 6: Response for Means Main Effects Plot for SN ratios*

| LEVEL | A | B | C | D |
|---|---|---|---|---|
| 1 | 0.9322 | 0.9011 | 0.9211 | 0.9234 |
| 2 | 0.8845 | 0.9367 | 0.9167 | 0.8789 |
| 3 | 0.8945 | 0.8734 | 0.8734 | 0.9089 |
| Delta | 0.0478 | 0.0633 | 0.0478 | 0.0445 |
| Rank | 2.5 | 1 | 2.5 | 4 |

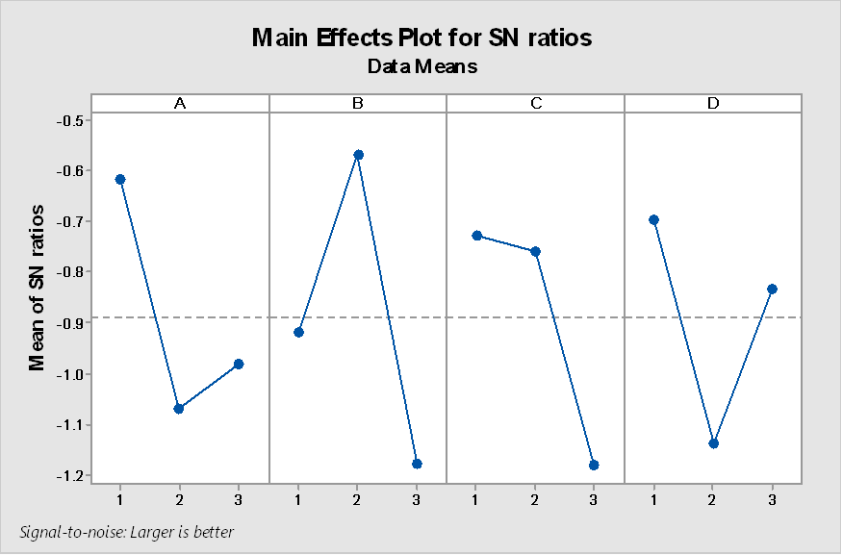


*Fig.2: Main Effects Plot for S/N Ratio*

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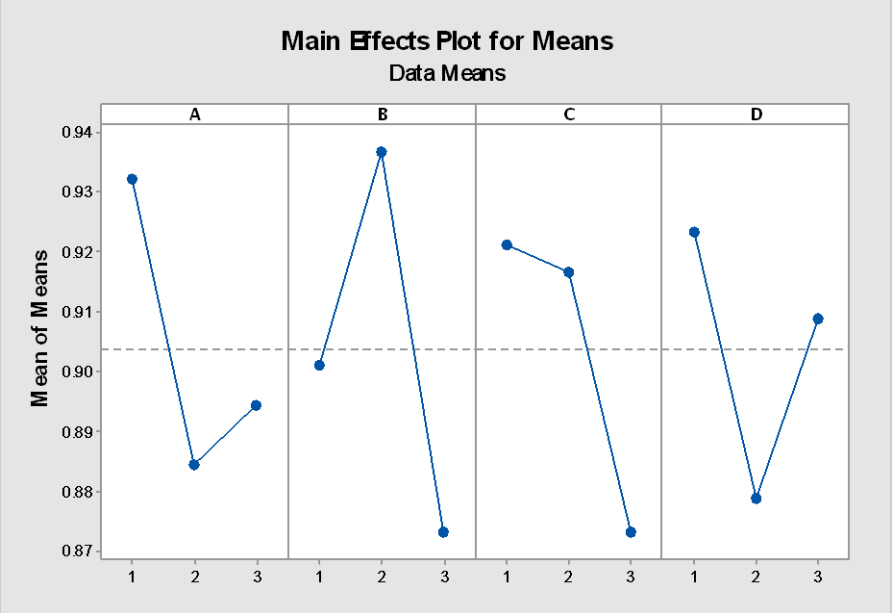


*Fig.2: Main Effects Plot for Mean.*

### 4.2 Analysis of Variance (ANNOVA)

**Model Summary**

S R-sq R-sq(adj) R-sq(pred)
* 95.00%

**Regression Equation**

MRR = 0.9037 + 0.02851 A_1 - 0.01926 A_2 - 0.009256 A_3 - 0.002589 B_1+ 0.03294 B_2 - 0.03036 B_3 + 0.01741 C_1 + 0.01294 C_2 - 0.03036 C_3 + 0.01964 D_1 - 0.02482 D_2 + 0.005178 D_3

## 5. RESULTS AND DISCUSSION

**Material Removable Rate**

In case of MRR the most significant parameter is feed which is having rank 1 in table 6 and with the analysis of S/N Ratio graphs the predicted optimal parameter setting for maximum MRR at spindle speed (A1, 200), feed (B2,1000) , depth of cut (C1, 0.01) and width of cut (D1,0.1). According to this procedure' optimal parameter sets confirmation test is done and found MRR is (0.98g/min).

## 6.0 CONCLUSION

This paper has discussed the feasibility of machining Cast iron by CNC finishing machine with a Carbide Tool. The signal to noise ratio has been used to determine the main effects significant factors and optimum machining condition to the performance of finishing

operation in cast iron based on the results presented here in, We can conclude that, the Feed Rate largely affects the MRR rather than Speed, Depth of cut and width of land.

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