

# Optimization of process parameters of CNC Milling machine for mild steel using Taguchi design and Single to Noise ratio Analysis

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## Abstract

In this paper signal-to-noise ratio method is applied to find optimum process parameters for finishing operation of mild steel with the help of CNC milling machine and high speed steel 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) with consideration of high surface finish and 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. And spindle speed is the most effective factor for surface roughness. Multiple regression equation are formulated for estimating predicted value surface roughness and material removal rate

**Keywords:** *CNC milling machine, surface roughness, material removal rate (MRR), Taguchi method, ANOVA, S/N Ratio MRR&SR*

## 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 mild steel work piece and high speed steel tool. The personnel industry as well as in research and development is required maintain surface roughness and MRR. Mild steel is extensive used us a main engineering material in various industry such as air craft and aerospace industry impact of finishing parameter such as speed (200,1000,2000) in rpm. Feed rate (200,1000,2000) mm/minute, depth of cut (.01,.05,.1) in mm and width of cut (0.1,0.2,0.4) in mm. The finishing tool diameter is constant in 6 mm. 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

machining. Taguchi designs provide a powerful and efficient method for designing processes that operate consistently and optimally over a variety of conditions. In this paper the finishing of mild steel with parameters of finishing at three levels and four factor each. The main objective of taguchi methodology to find a specific range and interaction to achieve the lowest surface roughness value and highest material removal rate.

## 2. Experimental Processes

### 2.1 Work piece Material

Finishing operation will be performed on Mild steel work piece. Mild steel are soft, ductile and easily machined. The composition of mild steel contains carbon (0.05% to 0.3%) and small quantities of manganese (Mn), silicon (Si), phosphorus (P), sulphur (S) are material related properties. Experiments were performed using a CNC vertical Milling machine. A rectangular mild steel plate of size 100 mm × 76 mm × 12 mm in shaping machine for performing CNC drilling machine. Holy oil was used as the coolant fluid in this experiment. Young's Modulus (210 GPa), Poisson's Ratio (0.29), Density (7.8 g/cm<sup>3</sup>), Melting Point (1400°C), Modulus of elasticity (200 GPa), Bulk Modulus (140 GPa).

### 2.2 High speed steel:-

One of our tools for the CNC finishing operation will be the high speed steel. High speed steel (HSS) are used for making finishing tools, we used tool diameter 6 mm in the milling machine and point angle is 118°. This property allows HSS to finish faster than high carbon steel, hence the name high speed steel. At room temperature, in their generally recommended heat treatment, HSS grades generally display high hardness. The composition of high speed steel are carbon (0.6% to 0.75%), tungsten (14% to 20%), Chromium (3% to 5%), vanadium (1% to 1.5%), Cobalt (5% to 10%) and remaining is iron.

### 2.3 Plan of experiment:-

The plan of experiment is taken. A rectangular mild steel plate of size 100 mm × 76 mm × 12 mm. In this plate finishing operation are performed with 6 mm diameter of tool. The experiments were conducted according to Taguchi orthogonal array. Which helps in reducing the number of experiments. In this paper four parameters and three levels considered for experimental runs. Optimization for quality was carried out with signal to noise ratio and analysis of variance (ANOVA).



Figure:1 Image of Experimental workpiece.

## 2.4 Machining process

Calculating mass of each plate by the high precision digital balance meter before machining operation and before machine process CNC machine part programs for particular tool path of particular commands using various levels of spindle speed, feed rate, depth of cut and width of cut. The performing finishing machining operation .After that calculating mass of each work pies plate again by the digital balance meter. The MRR values were measured three times of each specimen and then, the material removal rate Values were average. The Ra values also measured three times on each specimen and the surface roughness (Ra) is measured with a mitutoyo surfest SJ-201 series 178 portable surface roughness tester instrument. Machining experiments for determining the optimal machining parameter were carried out by setting of spindle speed in the range of 200-2000 rpm, feed in the range of 200-2000 mm/min, depth of cut in the range of .01-.1 mm, width of cut in the range of .1-.4 mm and Essential parameter of the experiment are given in table 1.

Table:-1 Finishing machining condition

Work Condition	Description
Work piece	Mild Steel, Rectangular shape(100x76x10mm)
Spindle Speed	200 to 2000 rpm
Feed	200 to 2000 mm/min
Depth of cut	.01 to .1 mm
Width of cut	.1 to .4 mm
Coolant	Holy oil
Lubricant	Servo pat
Tool Diameter	6 mm



**Fig.2: CNC vertical milling machine used for experiment  
Machine Model: MTAB MAX MILL PLUS**



**Fig 3: Image of working Tool**

### 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 and SR were 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)	200	1000	2000	1. Material removal rate (g/min)
Feed Rate (mm/min.)	200	1000	2000	
Depth of cut (mm)	.01	.05	.1	2. Surface roughness (Ra)
Width of cut (mm)	.1	.2	.4	

### 3.2 Methodology

#### SIGNAL TO NOISE RATIO CALCULATION

Quality Characteristics:

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

$$S/N = -10 \log \left( \frac{1}{n} \sum \left( \frac{1}{y^2} \right) \right) \dots \dots \dots 1$$

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

$$S/N = -10 \log \left( \frac{y}{s^2 y} \right) \dots \dots \dots 2$$

$$S/N = -10 \log \left( \frac{1}{n} \sum (y^2) \right) \dots \dots \dots 3$$

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

In this paper, analysis based on the taguchi method is done by Signal to noise ratio (MINI-TAB-16 Software) to determine the main effects of the process parameters, to perform the analysis of variance (ANOVA) and to establish the Signal to noise ratio optimum conditions. The main effects analysis is used to study the trend of the effects of each of the factors, as shown in figures 4 and 5. 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 taguchi analysis parameter for spindle speed (A) feed (B) depth of cut (C) and width of cut (D). The response table 6 for MRR use in the signal to noise ratio larger is the better and response table 7 for mean effects plot for S/N ratio the spindle speed is less in level (3) compare to the other level. the feed is the high at level (1) and depth is minimum at level (2) all this case the MRR is maximum. the surface roughness is calculated by the same procedure. table 8 & 9 for Signal to Noise Ratios Smaller is better and Means Main Effects Plot for S/N ratios. The surface roughness is minimum at high spindle speed, low feed rate and also low depth of cut.

**Table 3: L<sub>9</sub> table and observed values**

No. of Trial	Control Parameter(level)				Result/Observed Value					
	Spindle Speed(S)	Feed (F)	Depth of Cut(D)	Width of Cut(W)	MRR (g/min.)			SR (Ra)		
					1	2	3	1	2	3
1	200	200	0.01	0.1	0.98	0.96	0.96	4.22	4.02	4.02
2	200	1000	0.05	0.2	0.93	0.97	0.96	3.88	3.86	3.83
3	200	2000	0.1	0.4	0.86	0.87	0.90	3.96	3.80	3.83
4	1000	200	0.05	0.4	0.89	0.90	0.91	3.85	3.85	3.83
5	1000	1000	0.1	0.1	0.90	0.92	0.90	3.83	3.82	3.86
6	1000	2000	0.01	0.2	0.83	0.86	0.85	3.12	3.21	3.30
7	2000	200	0.1	0.2	0.85	0.83	0.83	3.00	3.12	3.23
8	2000	1000	0.01	0.4	0.97	0.95	0.93	3.20	3.00	3.25
9	2000	2000	0.05	0.1	0.90	0.91	0.88	3.25	3.24	3.22

**Table 4: S/N Ratio 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

**TABLE 5: S/N Ratio for SR (Smaller is Better)**

No. of Trial	1	2	3	Average response value	SNRA	MEAN
1	4.22	4.02	4.02	4.0867	-12.2275	4.0867
2	3.88	3.86	3.83	3.8567	-11.7243	3.8567
3	3.96	3.80	3.83	3.8633	-11.7392	3.8633
4	3.85	3.85	3.83	3.8433	-11.6941	3.8433
5	3.83	3.82	3.86	3.8367	-11.6792	3.8367
6	3.12	3.21	3.30	3.2100	-10.1301	3.2100
7	3.00	3.12	3.23	3.1167	-9.8739	3.1167
8	3.20	3.00	3.25	3.1500	-9.9662	3.1500
9	3.25	3.24	3.22	3.2367	-10.2020	3.2367

## 4 Taguchi Design: MINITAB Analysis

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

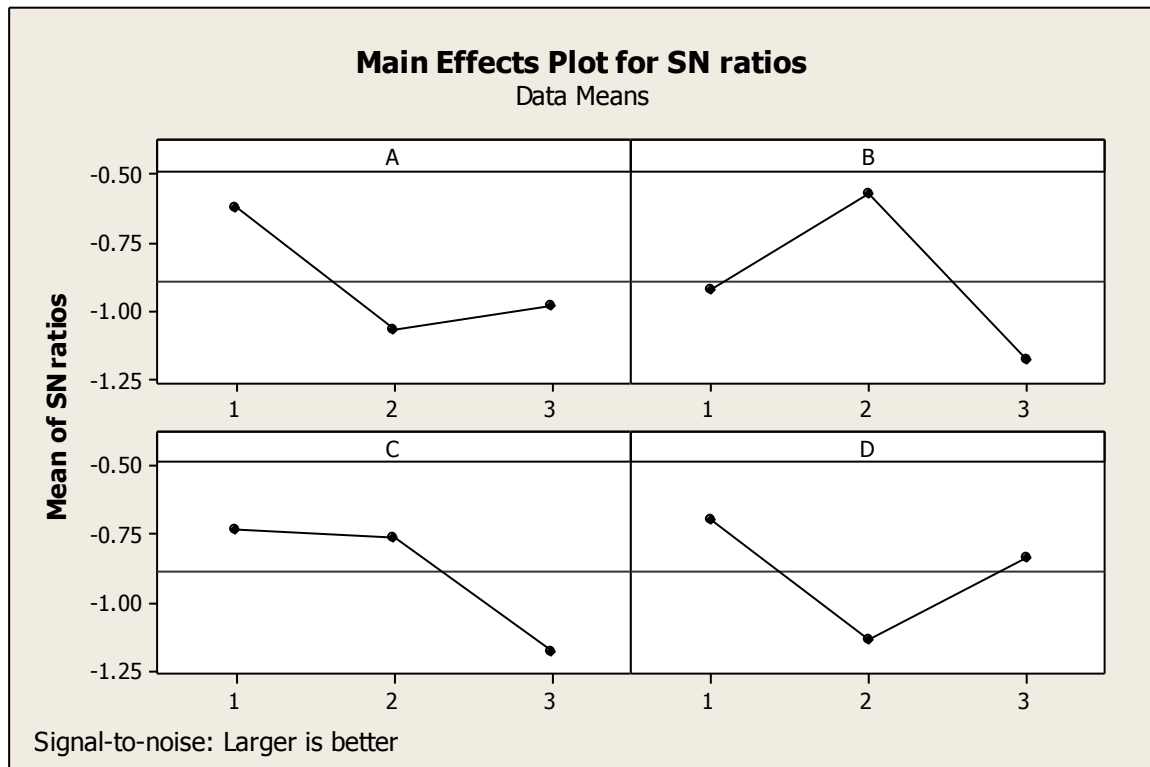
**Table 6: Response for Signal to Noise Ratios (Larger is better)**

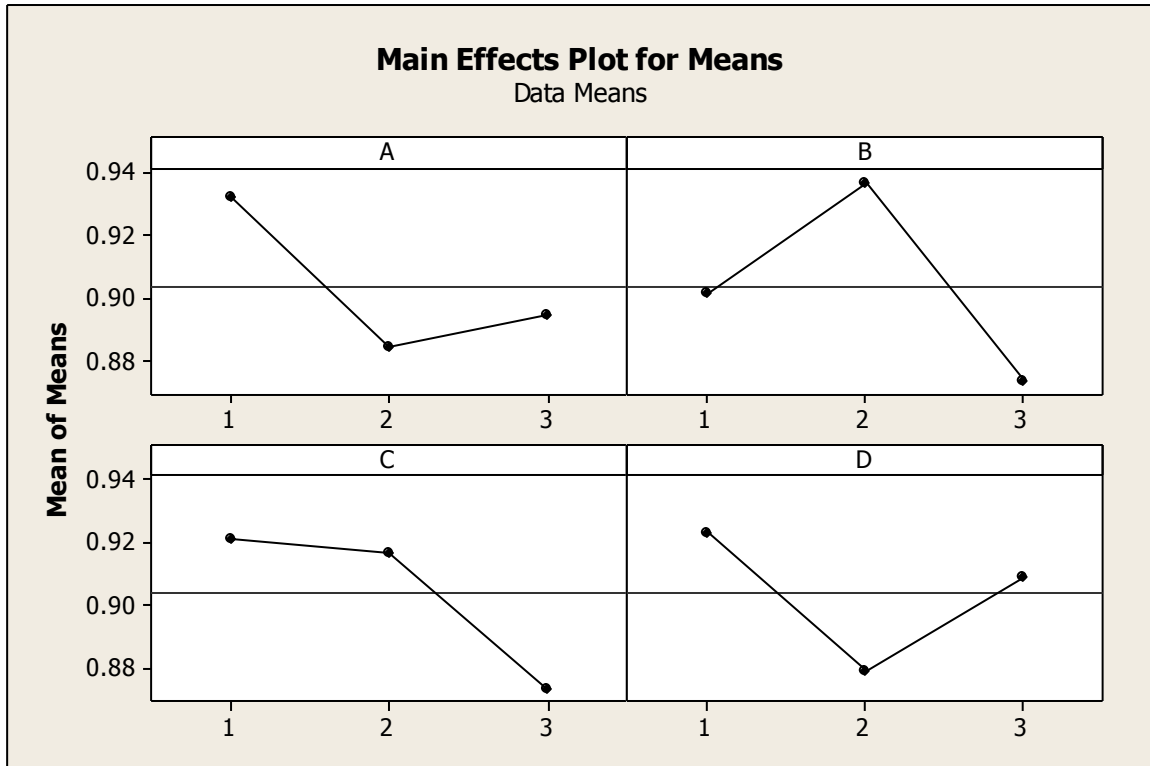
LEVEL	A	B	C	D
1	-0.6175	-0.9193	-0.7284	-0.6973
2	-1.0704	-0.5706	-0.7592	-1.1365
3	-0.9804	-1.1785	-1.1808	-0.8346
Delta	0.4529	0.6079	0.4524	0.4392
Rank	2	1	3	4

**Table 7: 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.4: Main Effects Plot for S/N ratios**



**Fig.5: Main Effects Plot for Means****4.2 Taguchi Analysis: response versus A, B, C****Table 8 : Response for Signal to Noise Ratios (Smaller is better)**

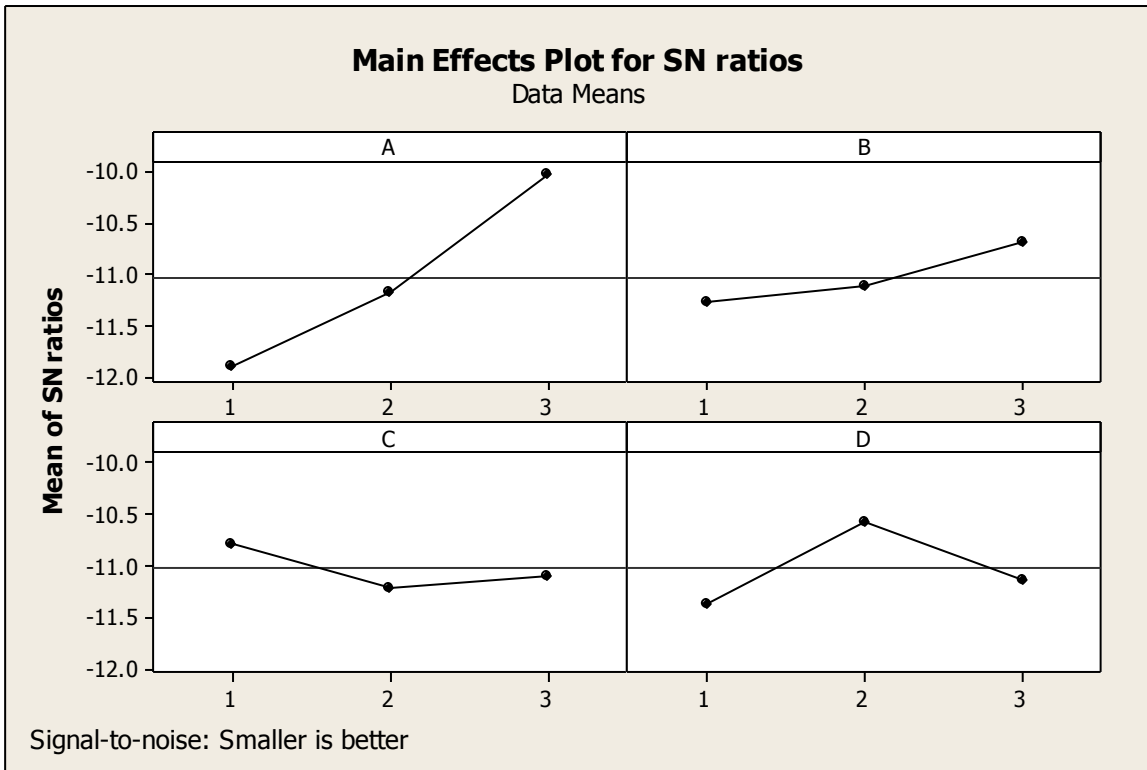
Level	A	B	C	D
1	-11.90	-11.27	-10.77	-11.37
2	-11.17	-11.12	-11.21	-10.58
3	-10.01	-10.69	-11.10	-11.13
Delta	1.88	0.57	0.43	0.79
Rank	1	3	4	2

**Table 9 : Response for Means Main Effects Plot for S/N**

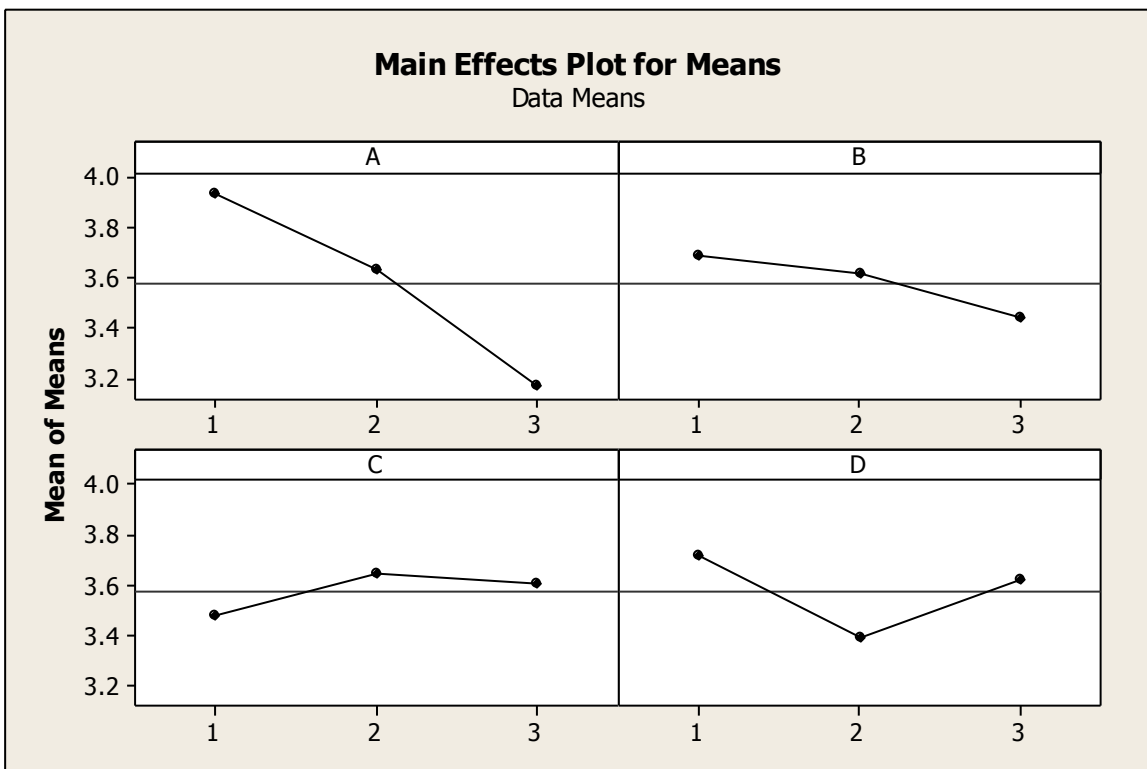
Level	A	B	C	D
1	3.936	3.682	3.482	3.720
2	3.630	3.614	3.646	3.394
3	3.168	3.437	3.606	3.619
Delta	0.768	0.246	0.163	0.326
Rank	1	3	4	2



**Fig.6: Main Effects Plot for SN ratios**



**Fig.7: Main Effects Plot for Means**



## 5. Results and Discussion

### 5.1 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 procedures' optimal parameter sets confirmation test is done and found MRR is (0.98g/min). Which shows the successful implementation of taguchi methodology in CNC drilling machine.

### 5.2. Surface Roughness

In case of SR the most significant parameter is spindle speed which is having rank 1 in table 8 and with the analysis of S/N Ratio graphs the predicted optimal parameter setting for minimum SR at spindle speed (A3, 2000), feed (B3,2000) and depth of cut (C1,0.01) and width of cut (D2,0.2). According to this procedures' optimal parameter sets confirmation test is done and found SR is (3.05Ra). Which shows the successful implementation of taguchi methodology in CNC drilling machine.

### Conclusion

This paper has discussed the feasibility of machining Mild Steel by CNC finishing machine with a HSS 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 mild steel based on the results presented here in, We can conclude that, the Spindle Speed of finishing machine Tool mainly affects the SR. The Feed Rate largely affects the MRR.

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