A REVIEW AND CASE STUDY ON TAGUCHI OPTIMIZATION OF MACHINING PARAMETERS FOR MILD STEEL USING SNR METHOD

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ABSTRACT

This study is intended to present a straightforward and computationally efficient methodology for optimizing the machining parameters of mild steel in CNC milling machine. In this paper SNR (signal-to-noise ratio) method is applied to get the optimum machining parameters for finishing operation of mild steel by using the CNC milling machine and high speed steel tool. The optimum selection of machining parameters plays a significant role to ensure the quality of product, to reduce the machining process cost and to increase the productivity. In this case we present the optimization aspects of machining parameters of mild steel material by using the Taguchi methods on CNC milling machine with high speed steel tool. In addition, a new ANOVA analysis on the L_9 orthogonal array with three factors is performed and results indicate that among the parameters considered (i.e., the tool rotational speed, transverse speed, and the axial force), the most significant parameter on the machining quality is the rotational speed, followed by the axial force and transverse speed.A L_9 orthogonal array and analysis of variance (ANOVA) are applied to study the performance characteristics of machining parameter (spindle speed, feed, depth and width) with consideration of high surface finish and high material removal rate (MRR). ANOVA was used to find out the level of significance of machining parameters and finally in the end the confirmation experiment was conducted to validate the effectiveness of the present work. The results obtained by the Taguchi method and SNR will be closely related to the most effective factor to the surface roughness. For estimating the predicted value of the multiple regression equation are formulated by the value of material removal rate and surface roughness.

Keywords: CNC milling machine, machining process, material removal rate (MRR), Taguchi method, ANOVA , S/N Ratio MRR&SR, L_9 orthogonal array.

INTRODUCTION

In today's manufacturing environment, many large industries have attempted to introduce the highly automated and computer-controlled machines as their strategy to adapt to the ever-changing competitive market requirement. 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. Due to high capital and machining costs, there is an economic need to operate these machines as efficiently as possible in order to obtain the required pay back. The success of the machining operation depends on the selection of machining process parameters.Determination of optimum process parameters of any machining process is usually a difficult work where the following aspects are required: knowledge of manufacturing process, empirical equations to develop realistic constraints, specification of machine tool capabilities, development of effective optimization criteria, and knowledge of mathematical and numerical optimization techniques. The selection of optimum process parameters play a significant role to ensure quality of product, to reduce the machining cost, to increase productivity in computer-controlled machining processes and to assist in computer-aided process planning. The present study is mainly focused on the optimization aspects of CNC milling machining process for mild steel using high speed steel tool.

Genichi Taguchi, a Japanese engineer, proposed several approaches to experimental designs that are sometimes called "Taguchi Methods." These methods utilize two-, three-, and mixed-level fractional factorial designs. Large screening designs seem to be particularly favoured by Taguchi adherents.Taguchi refers to experimental design as "off-line quality control" because it is a method of ensuring good performance in the design stage of products or processes. Some experimental designs, however, such as when used in evolutionary operation, can be used on-line while the process is running.

Signal-to-noise ratio (abbreviated SNR or *S/N*) is a measure used in science and engineering that compares the level of a desired signal to the level of background noise. It is defined as the ratio of signal power to the noise power, often expressed in decibels. A ratio higher than 1:1 (greater than 0 dB) indicates more signal than noise. While SNR is commonly quoted for electrical signals, it can be applied to any form of signal (such as isotope levels in an ice core or biochemical between cells).

Design optimization for quality was done and SNR and variance (ANOVA) were carried out using output results of the experiment to confirm effectiveness of this approach. Engineers are widely using the SNR methodology of Taguchi to get the optimal parameters for material removal rate and surface roughness in finishing operation which is based on experimental results done on mild steel work piece and high speed steel tool. 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 L_9 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 reason for this study is to get a specific range and interaction to achieve the lowest surface roughness value and highest material removal rate.

EXPERIMENTAL SET-UP AND SELECTION OF MACHINING PROCESS PARAMETERS:

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 conation carbon (0.05%to0.3%) 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 (100mm×76mm×12mm) in shaping machine for performing CNC drilling machine. Holy oil was used as the coolant fluid in this experiment .Young's Modulus (210GPa), Poisson's Ratio (0.29) Density (7.8g/cm³), Melting Point (140ºC) Modulus of elasticity (200GPa) Bulk Modulus (140GPa).

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 118º This property allows HSS to finishing 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%to0.75%) tungsten (14%to20%),Chromium (3%to5%) vanadium (1%to1.5%), Cobalt (5%to10%) and remaining is iron.

PLAN OF EXPERIMENT

The plan of experiment is to take a rectangular mild steel plate of size 100mm×76mm ×12mm. In this plate finishing operation are perform with 6 mm diameter of tool. The experiments were conducted according to Taguchi orthogonal array. This 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).

Figure-1: Experimental work piece.

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 mitutoyosurftest 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.

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

Table-1: Finishing machining condition

Figure-2: CNC vertical milling machine (**Machine Model:** MTAB MAX MILL PLUS)

Figure-3: Image of working Tool

DESIGN OF EXPERIMENT AND DATA ANALYSIS

Experiment design:

The experimental design procedure for the machining parameters, using the L_9 orthogonal array and SNR. 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.

Control parameters	levels			Observed Value
	1	2	3	
	Minimum	Medium	Maximum	
Spindle Speed's(rpm)	100	750	2000	Material removal rate (g/min)
Feed Rate (mm/min.)	100	750	2000	
Depth of cut (mm)	0.01	0.05	0.1	Surface roughness
Width of cut (mm)	0.1	0.2	0.4	(Ra)

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

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

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

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

DATA ANALYSIS

In this paper, analysis based on the Taguchi method is done by Signal to noise ratio(MINI-TAB- 16Software) 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 Taugchi analysis parameter for spindle speed (A) feed (B) depth of cut(C) and width of cut(D). The response table6 for MRR use in the signal to noise ratio larger is the better and response table7 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.table8&9 for Signal to Noise Ratios Smaller is better and Means Main Effects Plot for S/N ratios. The surface roughness is min at high spindle speed, low feed rate and also low depth of cut.

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	100	200	0.01	0.1	0.97	0.97	0.97	4.26	4.27	4.25
2	100	1000	0.05	0.2	0.95	0.99	0.97	3.99	3.98	3.93
3	200	2000	0.1	0.4	0.90	0.89	0.94	3.99	3.96	3.93
4	750	200	0.05	0.4	0.90	0.95	0.94	3.90	3.85	3.93
5	750	1000	0.1	0.1	0.93	0.95	0.95	3.89	3.82	3.87
6	750	2000	0.01	0.2	0.86	0.89	0.87	3.30	3.29	3.32
7	2000	200	0.1	0.2	0.87	0.86	0.85	3.08	3.12	3.18
8	2000	1000	0.01	0.4	0.98	0.97	0.96	3.15	3.07	3.19
9	2000	2000	0.05	0.1	0.92	0.93	0.90	3.30	3.26	3.27

Table-3: L_9 table and observed values

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

Table-4: S/N Ratio for MRR (Larger 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

Table-5: S/N Ratio for SR (Smaller is Better)

TAGUCHI DESIGN: MINITAB Analysis

Taguchi Analysis: response versus A, B, C

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 Signal to Noise Ratios (Larger is better)

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

Table-7: Response for Means Main Effects Plot for SN ratios

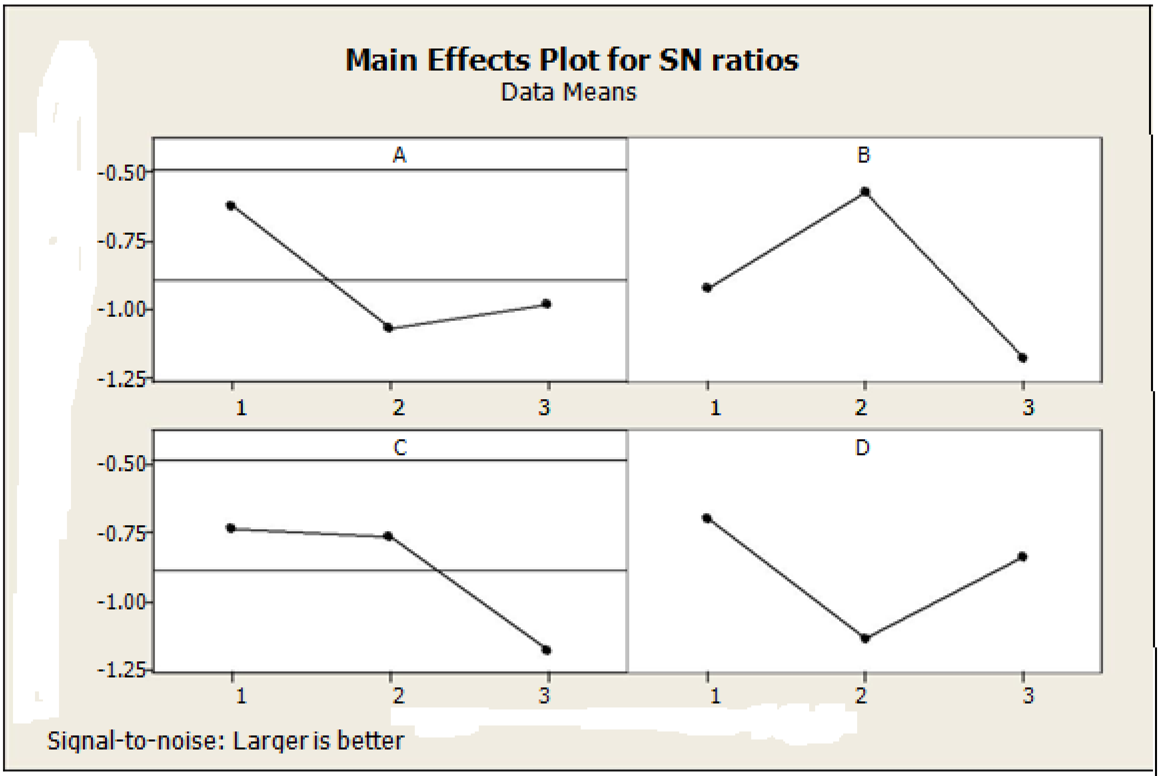

Figure-4: Main Effects Plot for S/N ratios

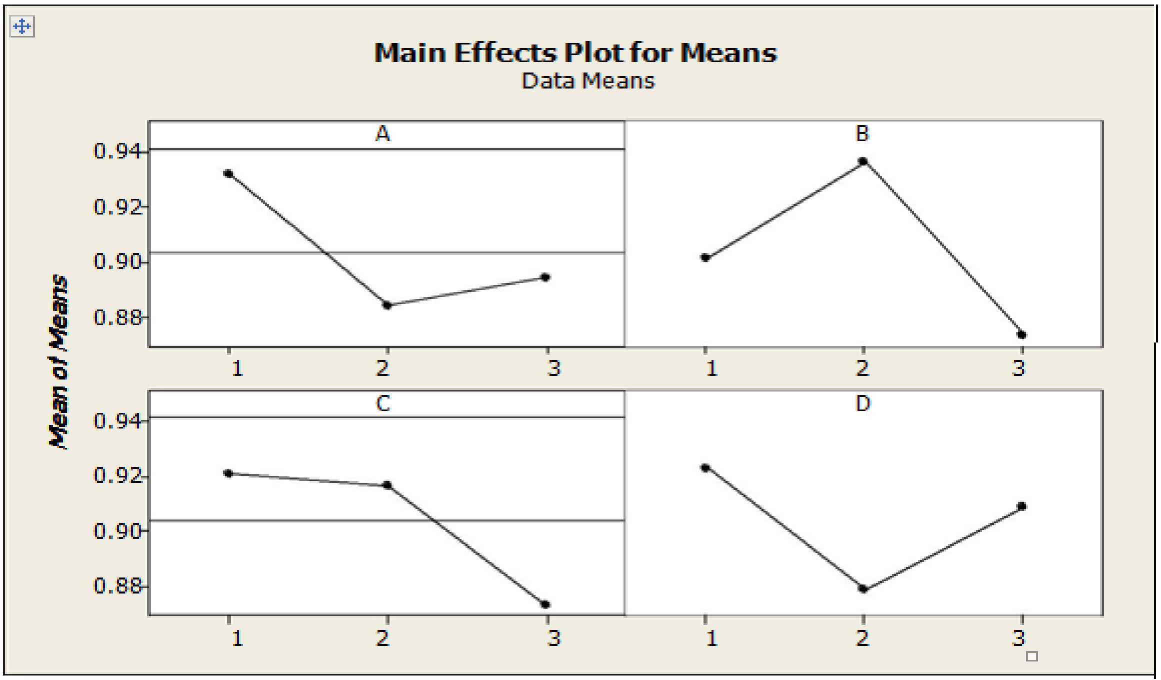

Figure-5: Main Effects Plot for Means

Taguchi Analysis: response versus A, B, C

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-8: Response for Signal to Noise Ratios (Smaller is better)

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

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

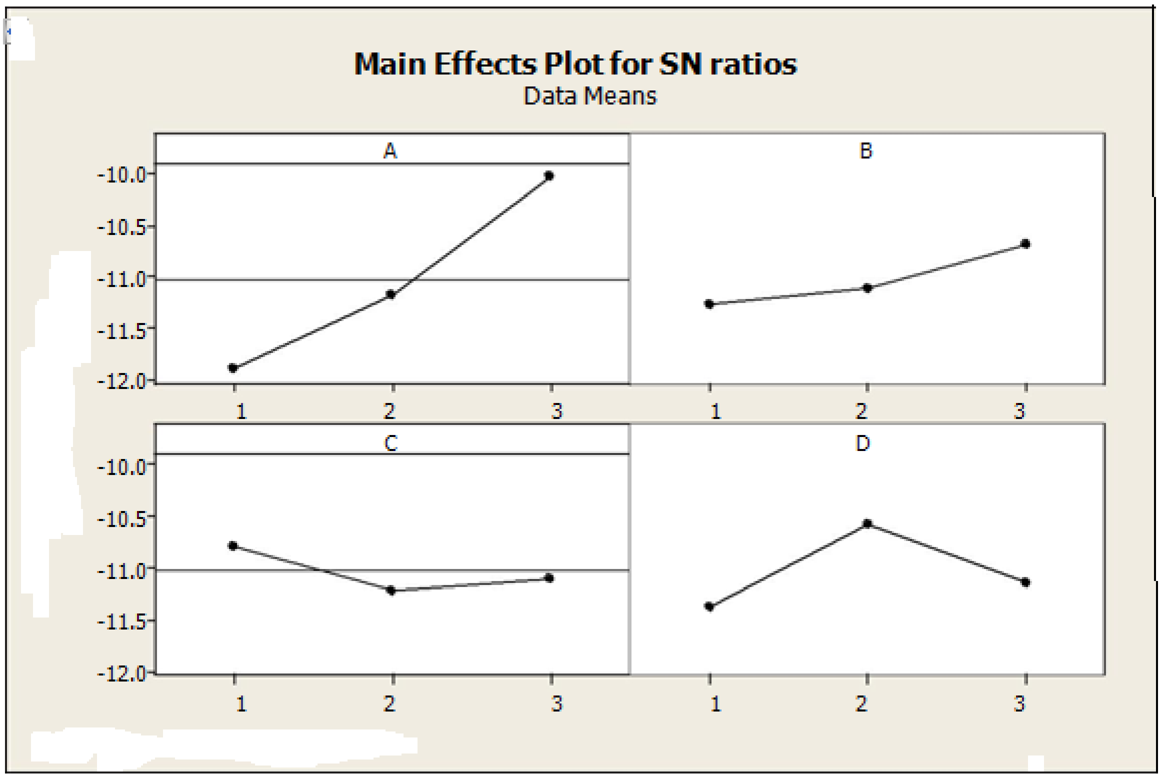

Figure-6: Main Effects Plot for SN ratios

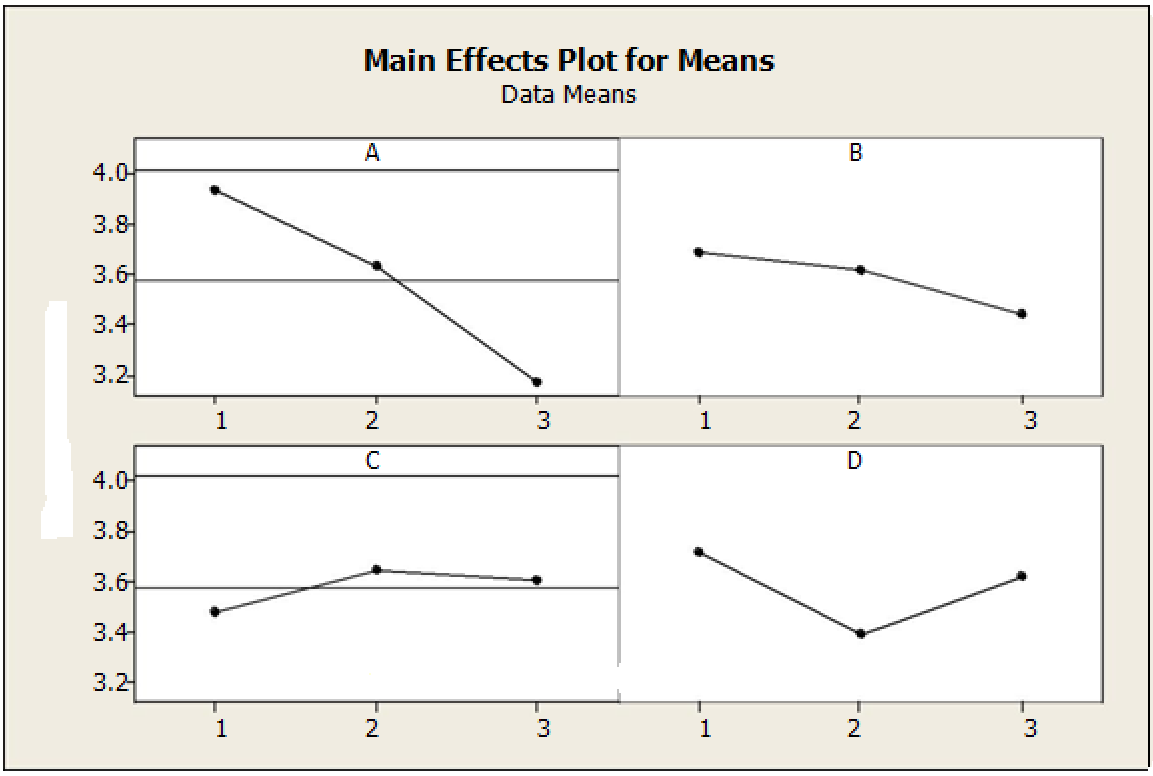

Figure-7: Main Effects Plot for Means

RESULTS AND DISCUSSION

Material Removable Rate (MRR)
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.

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 high speed steel 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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