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Study and Analysis of Material Removal Rate on Lathe Operation with Varing Parameters from CNC Lathe Machine

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ABSTRACT: In this era of mass manufacturing MRR (material removal rate) is of prime concern even in manufacturing using CNC machines. The main objective of today's modern manufacturing industries is to produce low cost and high quality product in short time. In order to improve the quality and to reduce the cost material removal rate should be optimum. In machining accurate dimensions is desired but with good product quality. Machining process involves many factors which affects the process directly or indirectly. The research study aims to analyze MRR by taking feed, depth of cut &spindle speed into consideration of Aluminum 6063 employing Taguchi method. A L9 Orthogonal array is used to performing the various experimental studies that analysis the MMR and analysis of surface roughness and signal to Noise Ratio (S/N ratio).

Keywords: MRR, Taguchi, Aluminum Alloy, Lathe Operation, ANOVA, S/N ratio.

I. INTRODUCTION

Today CNC has become an integral part of industry. The accuracy (dimensional) surface finish, precision which is achieved through CNC cannot be done or achieved through Conventional process. The MRR is a factor which rate affects the machining hour's rate and machining cost. Feed rates, spindle speed, depth of cut are the parameters which are taken in consideration. Turning is one of the machining processes which involve removal of extra/unwanted material from the surface of a rotating work piece. It is done with a single point cutting tool."Metal from outer periphery of a cylindrical work piece is removed and the volume of metal removed per unit time is known as Material Removal Rate (MRR)."In today's competitive environment machining technologies have been used to increase the output with the minimum effort or input which would increase the machining cost and increase the quality if machine part so all parameters incorporated with the process are analyzed. An experimental investigation approach was carried out to obtain the optimum value of MRR. Experimental design was dome through Taguchi method the influence of spindle speed, feed rate, and depth of cut on the material while machining, Significance of each factor and also the interaction of input parameters on output can be founded easily. Taguchi was employed because it is difficult to analysis the input parameters simultaneously. One factor on one time gives influence of one factor of output. The results obtained from the experimental study are used to annualized and evaluating the effects of various input parameters (spindle speed, federate, and depth of cut) on material removal rate.

Gaurav Kumar, Rahul Davis worked on Surface Roughness and Material Removal Rate in Milling Operation of AISI 410 Steel And Aluminium 6061 and founded that speed was the main factor which affects the surface finish of AISI 410 and none affects Aluminium 6061[1]. Adeel H. Suhail et al conducted experimental study to optimize the cutting parameters using two performance measures, roughness of surface and temperature of work piece's surface. Optimum cutting parameters were obtained by using Taguchi method. The orthogonal array, signal to noise (S\N) ratio and analysis of variance (ANOVA) were employed to study the performance in turning operation. The experimental results showed that the work piece surface temperature can be sensed and used effectively as an indicator to control the performance of cutting and improves the process of optimization [2]. K. Palanikumar, et al. discussed the application of the Taguchi method with fuzzy logic to optimize the parameters of machining for GFRP (Glass Fiber Reinforced Plastic) machining, composites with multiple characteristics. A multi response performance index (MRPI) was used for the optimization. The parameters of machining like cutting speed, work piece (fiber orientation), feed rate, depth of cut, and machining time were optimized with consideration of multiple performance characteristics like tool wear, metal removal rate, and surface roughness [3]. S. S. Mahapatra et al. an attempt has been made to generate a surface roughness prediction model and optimize the process parameters using Genetic algorithms [4]. (Lok and Lee, 1997) have evaluated the machining performance in terms of MRR and surface roughness on ceramics using wire electrical discharge machining[5]. Tong L. et al. (1997), presented a procedure in this research study to gain the optimization of multi-response problems in the Taguchi method which includes four phases, i.e., determination of optimal factor/level condition and performing the confirmation experiment, determination of the multi-response S/N ratio, computation of quality loss [6].

Feng. Cang-Xue (Jack) studied the impact of turning parameters on surface roughness. He studied the impact of Feed, Speed and Depth of Cut, Nose radius of tool and work material on the surface roughness. He found that the feed have major significant impact on the observed surface roughness and also observed that there were strong interactions among different turning parameters [7]. Krishankant at el worked on project of the turning of EN24 steel in order to optimize the turning process parameters for maximizing the material removal rate and founded that a greater S/N value corresponds to a better performance [8].
Saurabh S. worked on the effect of rake angle and feed rate in mild steel as workpiece for the optimization of MRR. For this they take different rake angles of 6,9,12 degree with fees rate of 0.05,0.07 and 0.10 rev/mm and concluded that feed has more effect then rake angle while machining[9]. Yogendra Tyagi performed parametric optimization of drilling machining process using different parameters such as feed rate, spindle speed, depth of cut to minimize surface roughness [10]. Kamal Hassan investigated the effects of operational parameters on Material Removal Rate (MRR) in turning of C34000 (Medium leaded Brass) and founded that feed rate Material removal rate is mainly affected by cutting speed and feed rate [11]. A. Mohanty *et al* studied MRR, Surface Roughness and microstructure in electrochemical machining of Inconel 825 and founded that as voltage increases MRR also increases and the tool feed rate as well and with the higher concentration surface roughness decreases and wise versa [12]. Srinivas Athreya, Dr Y.D. Venkatesh studied the procedure adopted in using Taguchi Method for a lathe facing operation. And concluded that taguchi can be performed with lesser number of experiments and taguchi can be applied for any kind of problems and it provides a simple and systematic approach for optimizing various process parameters [13].

II. MATERIAL AND METHODOLOGY

A. Experimental Details

The experiments are carried / performed on CNC lathe. The tool and material selected was **Aluminum 6063** and Carbide tool respectively. Three process parameters as already started above cutting speed (A), feed rate (B), and Depth of cut (C) were considered in the study employing Taguchi method.

B. Taguchi Method

When the number of process parameters increases the traditional methods requires large number of experiments and were very complicated and difficult to use. This method uses a special set of arrays called orthogonal arrays.

Taguchi recommends analyzing the mean response for each run in the inner array, and he also suggests analyzing variation using an appropriately chosen signal-to-noise ratio (S/N). There are 3 Signal-to-Noise ratios of common interest for optimization of Static Problems. We have taken "Larger the better" for maximization of Material Removal Rate (MRR).

C. Work Material

Aluminium 6063 is a medium strength alloy commonly referred to as an architectural alloy. The turning of Aluminium 6063 was done during designed experiments. Aluminium has good machining properties such as light weight and good surface finish can be achieved. It is normally used in intricate extrusions. It has a good surface finish, high corrosion resistance, is readily suited to welding and can be easily anodised.

D. Applications

6063 is typically used in:

- Architectural applications
- Extrusions
- Window frames
- Doors
- Shop fittings
- Irrigation tubing

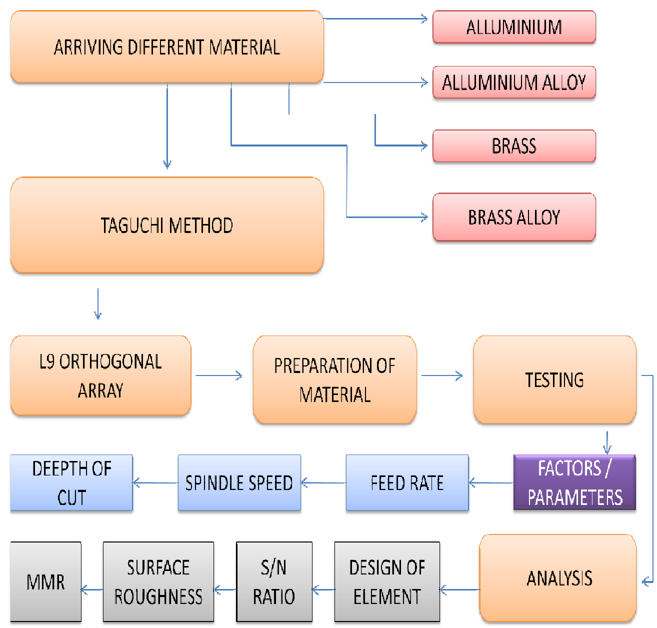


Fig. 1. Flow Chart Of Methedology.

E. Figures and Tables

Table : 3 Signal-to-Noise ratios of common interest for optimization of Static Problems Chart.

.Signal-to-noise ratio	Goal of the experiment	Data characteristics	Signal-to-noise ratio formulas
Larger is better	Maximize the response	Positive	S/N = -10 $*\log(\Sigma(1/Y^2)/n)$
Nominal is best	Target the response and you want to base the signal-to-noise ratio on standard deviations only	Positive, zero, or negative	S/N = -10 $*\log(\sigma^2)$
Smaller is better	Minimize the response	Non-negative with a target value of zero	S/N = -10 $*\log(\Sigma(Y^2)/n))$

TABLE NUMBER 2: Chemical Composition of Aluminum 6063.%

Element	Composition
Magnesium (Mg)	0.45 - 0.90
Silicon (Si)	0.20 - 0.60
0Iron (Fe)	0.0 - 0.35
Others (Total)	0.0 - 0.15
Chromium (Cr)	0.0 - 0.10
Copper (Cu)	0.0 - 0.10
Titanium (Ti)	0.0 - 0.10
Manganese (Mn	0.0 - 0.10
Zinc (Zn)	0.0 - 0.10
Other (Each)	0.0 - 0.05
Aluminium (Al)	Balance

TABLE NUMBER 3: Fabrication & Weld Ability Chart.

Fabrication & Weldability	
Solderability	Good
Weldability – Gas	Excellent
Weldability – Arc	Excellent
Weldability – Resistance	Excellent
Brazability	Excellent
Workability – Cold	Acceptable
Machinability	Good

Table Number 4: Symbol Chart of Factors.

Factors	Symbol
Spindle Speed	Factor A
Feed Rate	Factor B
Depth of Cut	Factor C

TABLE NUMBER 5: Chart for Level and Control Factors.

Control Factors	Level 1	Level 2	Level 3	Units
Factor A	165.5	255.5	391.5	RPM
Factor B	65.5	130	256.5	mm/min
Factor C	0.2	0.3	0.4	Mm

TABLE NUMBER 6: Set Of Experiment L9 Orthogonal Array Chart for Three Factors with Three Levels

EXPERIMENT NUMBER	SPINDLE SPEED	FEED RATE	DEPTH OF CUT
1	165.5	80	0.2
2	165.5	100	0.3
3	165.5	120	0.4
4	255.5	80	0.3
5	255.5	100	0.4
6	255.5	120	0.2
7	391.5	80	0.4
8	391.5	100	0.2
9	391.5	120	0.3

TABLE NUMBER 7: Different value of MRR and Surface Roughness with varying samples.

MRR (cubic meter per minute)	SURFACE ROUGHNESS (Ra)	SURFACE ROUGHNESS (Rq)
0.0000025	2.6	2.9
0.0000047	1.8	2.2
0.0000075	1.4	1.7
0.0000058	2.2	2.4
0.0000096	1.6	1.9
0.0000058	0.9	1.3
0.0000118	1.1	1.4
0.0000074	0.8	1.2
0.0000133	1.6	1.8

TABLE NUMBER 8: L9 Orthogonal Array Experiment Chart.

EXPERIMENT NO.	P1	P2	P3
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

III. MATHEMATICAL MODEL

MRR is the volume of material removed per minute. The higher you're cutting parameters, the higher the MRR. Surface roughness often shortened to roughness, is a component of surface texture. It is quantified by the deviations in the direction of the normal vector of a real surface from its ideal form. If these deviations are large, the surface is rough; if they are small, the surface is smooth. In surface metrology, roughness is typically considered to be the high-frequency, short-wavelength component of a measured surface. However, in practice it is often necessary to know both the amplitude and frequency to ensure that a surface is fit for a purpose.

There are many different roughness parameters in use, but is by far the most common, though this is often for historical reasons and not for particular merit Ra, as the early roughness meters could only measure. Other common parameters include Rq, Rt, and Rz. Some parameters are used only in certain industries or within certain countries.

F. Abbreviations and Formula Used:

N=Rotational Speed
F=Feed Rate, mm/rev or in/rev
v=Feed rate, or linear speed of the tool along workpiece length, mm/min or in/min=fN
V= surface speed of workpiece, m/min or ft./min
$=\pi D_o N$ (for max. speed)
$=\pi D_{avg} N$ (for avg. speed)
L= length of cut, mm or in
D_o = original dia. of workpiece
D_f = final dia. of workpiece
D_{avg} = Avg. dia. of workpiece
$= (D_o+D_f)/2$
D= depth of cut, mm
$= (D_o-D_f)/2$
T= cutting time
= L/fN
MRR= $=\pi D_{avg} d\ f\ N$ mm^3/min

B. Nomenclature

s : Spindle speed, rpm.
f : Feed rate, mm/rev.
d : Depth of cut (DOC), mm.
D_i : Initial diameter of the metal bar, mm.
D_f : Final diameter of the metal bar, mm.
L : Cutting length of work piece, mm.
T : time, sec.
D_{avg} : Average diameter of the cutting section, mm.
Rq : root mean squared
Ra : arithmetic average
M.R.R. : Metal removal rate, mm3/sec.
S/N ratio: Signal to noise ratio.

IV. RESULT AND DISSCUSSION

It can be seen from above 9 sets of experiments that Material Removal Rate of experiment 9 is highest with feed rate of 120mm/min, spindle speed of 165.5rpm and depth of cut of .2mm.

While Surface Finish of the experiment 8 is very fine it has Spindle Speed of 391.5rpm, feed rate of 100 mm/min and Depth of cut of .2mm. From figure 5 we can see that Spindle Speed is found to be the most significant factor which affects the MRR and Depth of Cut stands at second rank while feed rate has the minimum effect on MRR.

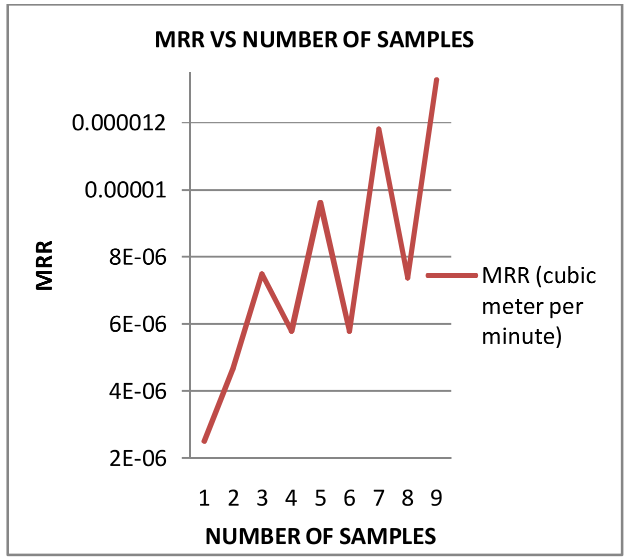


Fig. 2. Graphical Variation of Material Removal Rate with Varying Samples.

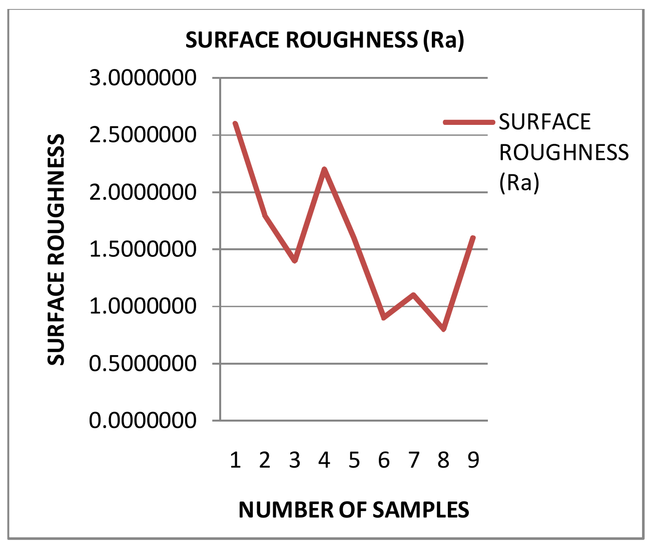


Fig. 3. Graphical Variation Surface Roughness (Ra) with Varying Samples.

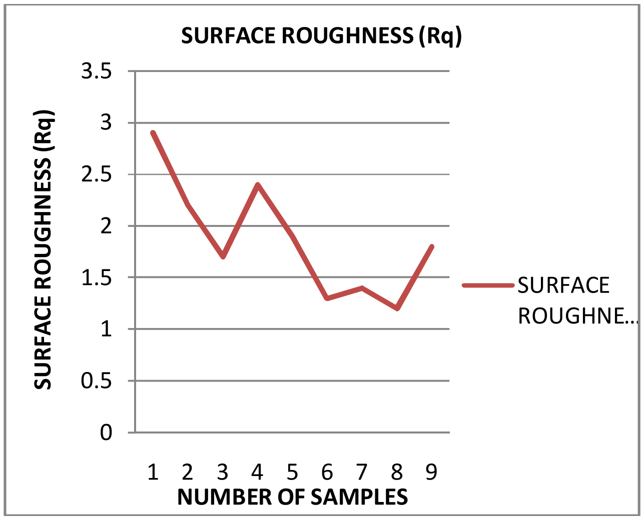
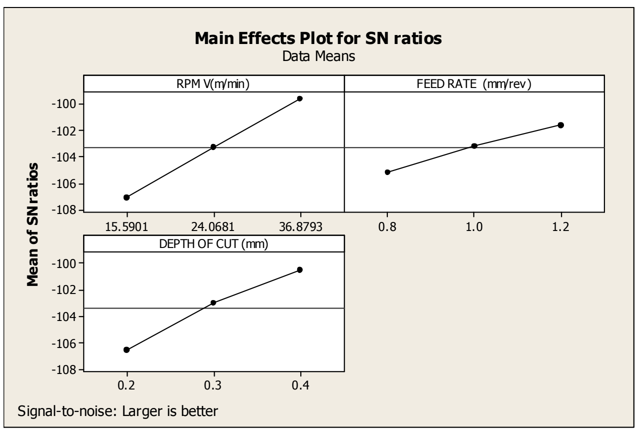


Figure4: Graphical Variation Surface Roughness (Rq) with Varying Samples

Fig. 5. Taguchi Analysis: SURFACE ROUG versus RPM V(m/min), FEED RATE (DEPTH OF CUT).



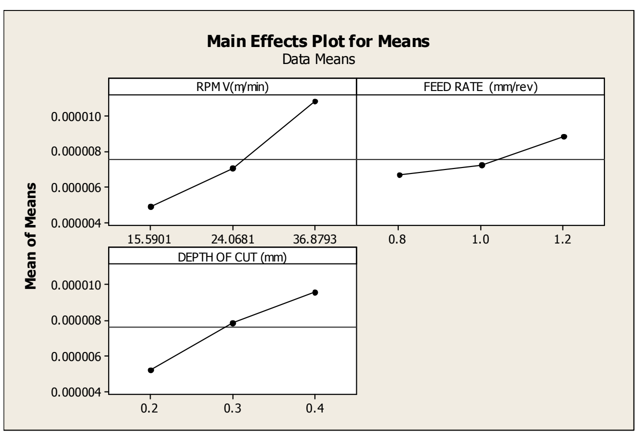


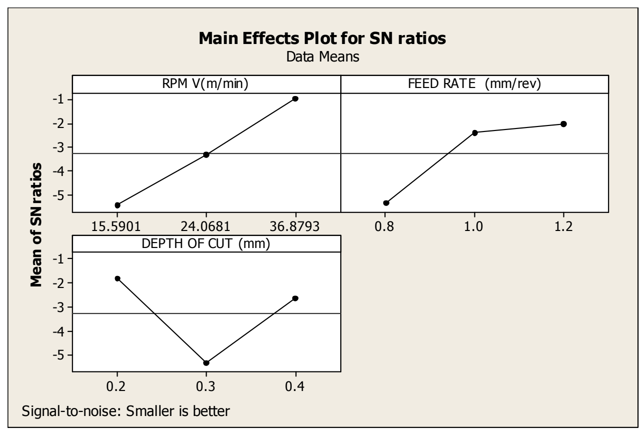
Table 9: Response Table for Signal to Noise Ratios Larger is better.

	RPM	FEED RATE	DEPTH OF
Level	V(m/min)	(mm/rev)	CUT (mm)
1	-107.06	-105.13	-106.49
2	-103.29	-103.19	-102.97
3	-99.58	-101.61	-100.47
Delta	7.48	3.52	6.02
Rank	1	3	2

Table 9: Response Table for Means.

	RPM	FEED RATE	DEPTH OF CUT
Level	V(m/min)	(mm/rev)	(mm)
1	0.000005	0.000007	0.000005
2	0.000007	0.000007	0.000008
3	0.000011	0.000009	0.000010
Delta	0.000006	0.000002	0.000004
Rank	1	3	2

Fig. 6. Taguchi Analysis: MRR (cubic m versus RPM V (m/min), FEED RATE, (DEPTH OF CUT).



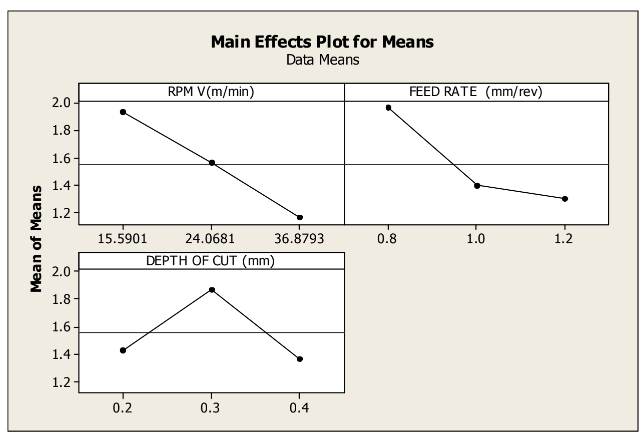


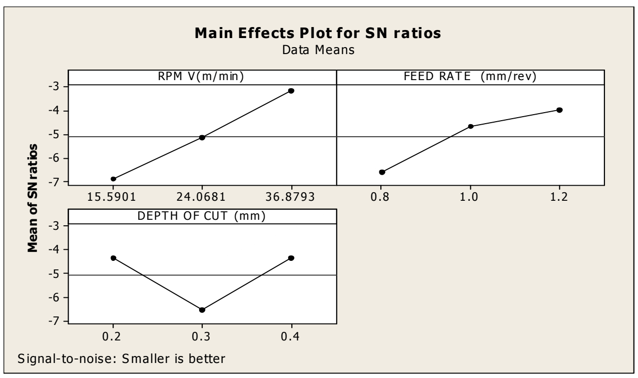
Table 9: Response Table for Signal to Noise Ratios Smaller is better.

Level	RPM V(m/min)	FEED RATE (mm/rev)	DEPTH OF CUT (mm)
1	-5.4425	-5.3253	-1.8154
2	-3.3386	-2.4165	-5.3454
3	-0.9907	-2.0299	-2.6109
Delta	4.4518	3.2953	3.5301
Rank	1	3	2

Table 9. Response Table for Means.

Level	RPM V(m/min)	FEED RATE (mm/rev)	DEPTH OF CUT (mm)
1	1.933	1.967	1.433
2	1.567	1.400	1.867
3	1.167	1.300	1.367
Delta	0.767	0.667	0.500
Rank	1	2	3

Fig. 7. Taguchi Analysis: SURFACE ROUG versus RPM V (m/min), FEED RATE, (DEPTH OF CUT).



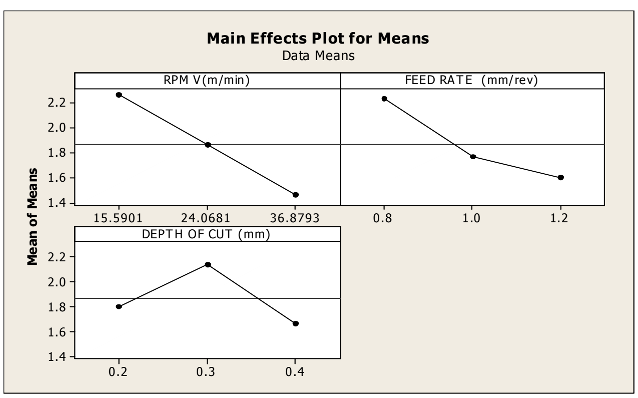


Table 13: Response Table for Signal to Noise Ratios Smaller is better.

Level	RPM V(m/min)	FEED RATE (mm/rev)	DEPTH OF CUT (mm)
1	-6.902	-6.592	-4.370
2	-5.153	-4.669	-6.519
3	-3.204	-3.998	-4.369
Delta	3.698	2.594	2.151
Rank	1	2	3

Table 14: Response Table for Means.

Level	RPM V(m/min)	FEED RATE (mm/rev)	DEPTH OF CUT (mm)
1	2.267	2.233	1.800
2	1.867	1.767	2.133
3	1.467	1.600	1.667
Delta	0.800	0.633	0.467
Rank	1	2	3

Fig. 8. CNC Lathe Machine.

IV. CONCLUSION

Turning tests were performed on Aluminium Alloy 6063 work piece using three different parameters. The influences of cutting speed, feed rate, and depth of cut were investigated on the machined surface roughness and Material Removal Rate (MRR). Based on the results obtained, the following conclusions have been drawn:

- The analysis of the experimental observations highlights that MRR in CNC turning process is greatly influenced by cutting speed followed by depth of cut.
- It is observed that the feed is most significantly influences the Surface Roughness (R_a).

G. Scope of Future Work

Some recommendations are given below:

1) The verification of the model for MRR may be developed by using other parameters.

2) Same analysis can be conducted for milling, facing, drilling, grinding and other metal removing processes.

3) Optimization of cutting parameters may be done by Fuzzy Logic and genetic algorithm.

4) Same analysis may be done for other materials (like Copper, Brass and Aluminum etc.).

5) Consideration of tool wear, surface roughness, and power consumption may be done.

6) Cutting fluids or lubricants are not used in this project work, cutting fluids can be used.

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