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Experimental investigation of process parameters on MRR and Surface roughness in turning operation on CNC Lathe machine for Mild Steel – E250: IS 2062

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***Abstract* - The performance of the manufactured products are often evaluated by several quality characteristics, responses and experimental techniques. In the present project a single characteristic response optimization model based on Taguchi Technique is developed to optimize process parameters such as spindle speed, feed and depth of cut. Taguchi's L9 orthogonal array is selected for experimental planning. The Analysis of experimental result showed that the combination of optimum levels of cutting speed, feed and depth of cut is essential to achieve simultaneous maximization of material removal rate and minimization of surface roughness. This project also aims to determine Analysis of Variance.**

Keywords - Optimization, MRR, Surface roughness, turning operation, CNC Lathe machine, E250: IS 2062

I. INTRODUCTION

In rivalry industry, each one assembling organization needs to fabricate ease and astounding item in a brief time to full fill client request. Robotized and adaptable assembling frameworks are utilized for that reason alongside computerized numerical control (CNC) machines that are fit for attaining high correctness and low preparing time. Cutting parameters are thought about surface Roughness, material removal rate (MRR), surface composition, and dimensional deviations of the item.(Behzad Jabbaripour *et.al.*)

A. *Turning Operation*

Turning is the removal of metal from the outer diameter of a rotating cylindrical work piece. Turning is used to decrease the diameter of the work piece, generally to a particular dimension, and to generate a smooth finish on the metal. Often the work piece will be turned so the adjacent sections have totally different diameters. In its basic type, it defined as the machining of an external surface:

- With the work piece rotating.
- With a single-point cutting tool, and
- With the cutting implement feeding parallel to the axis of the work piece and at a distance which will take away the outer surface of the work. (Mohd Naiim B Yusoff *et.al*)

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B. *Adjustable Cutting Factors in Turning*

The primary factors of turning operation are speed, feed, and depth of cut. Other factors like types of material and type of tool have a large influence, of course, but these three can be alter by adjusting the controls.(Figure ure 1)

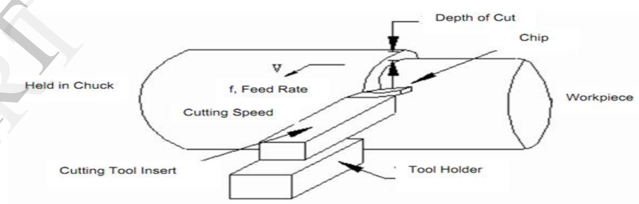

Figure 1: Adjustable parameters in turning operation

1) Speed:

Speed continually refers to the spindle and the work piece. Once it's explicit in revolutions per minute (rpm) it tells their rotating speed. However the necessary feature for a selected turning operation is that the surface speed, or the speed at that the work piece material is moving past the cutting implement.

$v = (\Pi * D * N) / 1000$ m/min

Here, v is the cutting speed in turning,

D is the initial diameter of the work piece in mm,

N is the spindle speed in RPM.

Feed:

Feed continuously refers to the cutter, and it's the speed at that the tool advances on its cutting path. On most power-fed lathes, the feed rate is directly associated with the spindle speed and is expressed in metric linear unit (of tool advance) per revolution (of the spindle), or mm/rev.

$F_m = f * N$ mm / min.

Here, F_m is the feed in mm per minute,

f is the feed in mm/rev,

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N is the spindle speed in RPM.

2) Depth of Cut:

Depth of cut is much self instructive . it's the thickness of the layer being removed (in one pass) from the work piece or the gap from the uncut surface of the work to the cut surface, expressed in , mm.

$d_{cut} = (D – d) / 2$ mm

Here, D is the initial diameter (in mm) of the job,

d is the final diameter (in mm) of the job.

C. Material removal rate (MRR)

The material removal rate (MRR) in turning operations is the volume of material/metal that is removed per unit time in mm3/min. For each revolution of the work piece, a ring shaped layer of material is removed.

$MRR = \{ \Pi * (D^2 – d^2) * l \} / \{ t * 4 \}$ mm^3 / min

Here, D is the initial diameter in mm,

d is the final diameter in mm,

l is the length in mm,

t is the time taken for machining in min.

D. surface roughness

Surface roughness, frequently reduced to roughness ad it can be measure by the texture of a surface. It is quantified by the vertical deviations of a real surface from its ideal form. If hese deviations are large, the surface is rough; if they are small the surface is smooth

II. METHODOLGY

A. Taguchi's Approach to Parameter Design

Taguchi's approach to parameter design provides the design engineer with a systematic and efficient method for determining near optimum design parameters for performance and cost (Kackar, 1985; Phadke, 1989; Taguchi 1986). The objective is to select the best combination of control parameters so that the product or process is most robust with respect to noise factors. A brief overview of Taguchi's approach for parameter design. (Figure 2) (Hemant Kumar Agarwal *et. al.*)

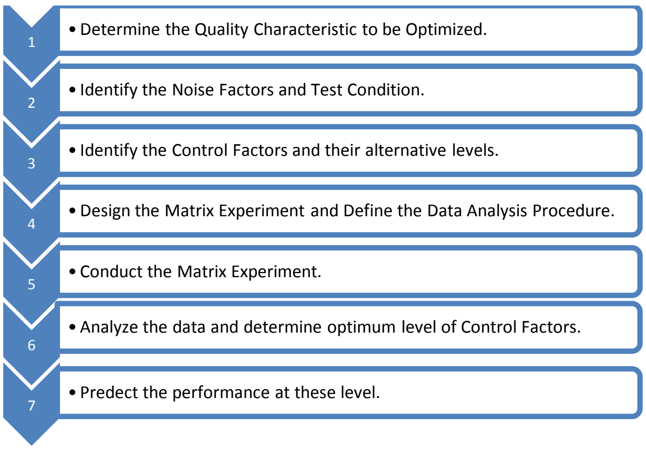

Figure: 2 Overview of Taguchi approach for parameter design

1) Determine the Quality Characteristic and to be optimized

The first step in the Taguchi method is to determine the quality characteristic to be optimized. The quality characteristic is a parameter whose variation has a critical effect on product quality. It is the output or the response variable to be observed. Examples are weight, cost, corrosion, target thickness, strength of a structure, and electromagnetic radiation.

2) Identify the Noise Factors and Test Conditions

To identify the noise factors to produce a negative impact on system performance and quality. Noise factors is a parameter which may either uncontrollable or are too expensive to control. Noise factors consist of variations in deterioration of components with usage, environmental operating conditions and variation in response between products of similar design with the similar input.

3) Identify the Control Parameters and Their Alternative Levels

To identify the control parameters thought to have significant effects on the quality characteristic. Control (test) parameters are those design factors that can be set and maintained. The levels (test values) for each test parameter must be chosen at this point. The numbers of levels, with related test values, for each test parameter was defining the experimental region.

4) Design the Matrix Experiment and Define the Data Analysis Procedure

A specific study is required to get proper orthogonal arrays for the noise and control. Taguchi gives many standard orthogonal arrays and corresponding linear graphs for this function (Taguchi and Konishi, 1987).Subsequent to selecting the appropriate orthogonal arrays, a process to simulate the variation in the quality characteristic due to the noise factors wants to be defined. A general approach is the use of Monte Carlo simulation (Phadke, 1989). However, for an precise estimation of the mean and variance, Monte Carlo simulation requires a huge number of testing conditions which can be expensive and time consuming. As an substitute, Taguchi proposes orthogonal array based simulation to assess the mean and the variance of a product's response ensuing from variations in noise factors (Bryne and Taguchi, 1986; Phadke, 1989; Taguchi, 1986). Using this approach, orthogonal arrays are used to sample the domain of noise factors. The experimental results for each combination of control and noise array experiment are denoted by $Y_{i,j}$

5) Conduct the Matrix Experiment

The Taguchi method may be used in any condition wherever there is a controllable process (Meisl, 1990; Phadke, 1989; Wille, 1990). The controllable process can be an real hardware experiment, computer models or systems of mathematical equations that can be effectively model for the response of many products and processes.

6) Analyze the Data and Determine the Optimum Levels

The optimal test parameter pattern within the experiment design must be determined, after the experiments have been conducted. For analysis of the results, the Taguchi method uses a statistical measure of performance called signal to-noise (S/N) ratio borrowed from electrical control theory (Phadke, 1989). The S/N ratio produced by Dr. Taguchi is a performance measure to select control levels that most excellent cope with noise (Bryne and Taguchi, 1986; Phadke, 1989). The S/N ratio takes both the mean and the variability into relation. In easiest form, the S/N ratio is the ratio of the mean (signal) to the standard deviation (noise). The S/N equation depends on the principle for the quality characteristic to be optimized. While there are many diverse probable S/N ratios, three of them are considered standard and are usually applicable in the situations below (Bryne and Taguchi, 1986; Phadke, 1989); a) Biggest-is-best quality characteristic (strength, yield), b) Smallest-is-best quality characteristic (contamination), c) Nominal-is-best quality characteristic (dimension). Whatever the type of quality or cost feature, the transformations are such that the S/N ratio is for all time interpreted in the same way: the larger the S/N ratio the better.

7) Predict the Performance at These Levels

With the help of Taguchi method for parameter designing, the predicted optimum setting are not required correspond to one of the rows of the matrix experiment. This is frequently the case when vastly fractioned designs are used (Bryne and Taguchi, 1986; Phadke, 1989). So, the final of step of an experimental confirmation is run using the predicted optimum levels for the control parameters being studied.

B. ANOVA (ANALYSIS OF VARIANCE)

Analysis of Variance (ANOVA) is a hypothesis-testing method used to analysis the equality of two or more population (or treatment) mean by examining the variances of samples which are taken. ANOVA permits to determine whether the differences between the samples are only due to random error or if there are systematic treatment effects which make the mean in one group to differ from the mean in another. Mainly ANOVA is used to compare the parity of three or more means, but when the means from two samples are compared using ANOVA it is similar to using a t-test to compare the means of independent samples. ANOVA is comparing the variance (or variation) between the data samples to variation within each particular sample. Whenever the between variation is much larger than the within variation, the means of different samples will not be equal. If samples will not be equivalent. If the between and within variations are approximately the equal size, then there will be no significant difference among sample means.

III. EXPERIMENTTION

Accordingly the present study has been done through the following plan of experiment. a) Checking and preparing the CNC Lathe Machine ready for performing the machining operation. b) Cutting MS bars by power saw and performing initial turning operation in Lathe to get desired dimension of the work pieces. c) Calculating weight of each specimen by the high precision digital weighing machine before machining. d) Performing straight turning operation on specimens in various cutting environments involving various combinations of process control parameters like: spindle speed, feed and depth of cut. e) Calculating weight of each machined component again by the digital weighing machine. f) Measuring surface roughness and with the help of a Roughness Tester Mitutoyo make.

A. Process variables and their limits

The process variables with their units for roughing operation and finishing operation are listed in Table 1 and 2 respectively.

Table 1: Level of process parameters for roughing operation

Parameter	Level 1	Level 2	Level 3
Spindle Speed (RPM)	800	1000	1200
Feed Rate (mm/ revolution)	0.15	0.18	0.2
Depth of cut (mm)	0.5	0.6	0.7

Table 2: Level of process parameters for finishing operation

Parameter	Level 1	Level 2	Level 3
Spindle Speed (RPM)	800	1000	1200
Feed Rate (mm/ revolution)	0.10	0.12	0.14
Depth of cut (mm)	0.3	0.4	0.5

B. Design of experiment

Experiments have been carried out using Taguchi's L9 Orthogonal Array (OA) experimental design which consists of 9 combinations of spindle speed, longitudinal feed rate and depth of cut. On the basis of design catalogue prepared by Taguchi, L9 Orthogonal Array design of experiment has been found suitable in the present work. It considers three process parameters (without interaction) to be varied in three discrete levels. The experimental design has been shown in Table 3 (all factors are in coded form).

Table 3 TAGUCHI'S L9 orthogonal array

Sr. No.	Factorial Combination		
	Spindle Speed (rpm)	Feed (mm/rev.)	Depth of Cut (mm)
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

C. Test Condition

Turning operation has been carried out on CNC turning machine (Batliboi Sprint20TC) using cutting insert Sandvik CNMG 12 04 08-PR 4225 for roughing operation and Sandvik TNMG 16 04 08-MM 2015 for finishing operation on material E250 : IS 2062 pipe at different levels of process parameters Spindle Speed, Feed and Depth of cut give by L9 orthogonal array. Weight before and after operation has been measured by digital weighing scale and Surface roughness value (Ra) measured by Portable surface roughness tester (Mitutoyo) SJ-201P. (Figure ure 3)

Figure: 3 Cnc Lathe Machine

D. *Roughness measurement*

Surface Roughness of the finished component were measured by Portable surface roughness tester (Mitutoyo) SJ-201P at Elecon Engineering Co. Ltd.

E. *Material removal rate measurement*

Material removal rate (MRR) has been calculated from the difference of weight of work piece before and after experiment.

MRR = (Wi - Wf) / (ρs * t) mm3 / min

Here W is the initial weight of work piece in g,

Wf is the final weight of work piece in g,

t is the machining time in minutes,

ρs is the density of mild steel (7.8 x 10-3g/mm3).

F. *Data collection*

MS pipe (84 * 62 * 150) required for conducting the experiment have been prepared first. Nine numbers of samples of same material and same dimensions have been made. After that, the weight of each samples have been measured accurately with the help of a high precision digital balance meter. Then, using different levels of the process parameters nine specimens have been turned in lathe accordingly. Machining time for each sample has been calculated accordingly. After machining, weight of each machined parts have been again measured precisely with the help of the digital weighing machine. Then surface roughness and surface profile have been measured precisely with the help of a portable surface roughness tester.

IV. RESULTS AND DISCUSSION

A. *Experiment results and Taguchi analysis*

A series of turning tests was conducted to assess the influence of turning parameters on material removal rate and surface roughness in turning E250. Experimental results of the material removal rate and surface roughness for turning with various turning parameters are shown in Table 4 and Table 5 respectively. A table also gives S/N ratio for material removal rate and surface roughness. The S/N ratio for each experiment of L9 was calculated. The objective of using the S/N ratio as a performance measurement is to develop products and process insensitive to noise factor.

B. Determination of optimal value

1) Material removal rate (MRR)

In response factors, the material removal rate (MRR), the larger-the-better characteristic was used and the largest resultant cutting force value would be the ideal situation. The graphs in Figure 4 & 5 are used to determine the optimal set of parameters from this experimental design. From the graphs, the control factor of spindle speed (A) at level 3 (1200 rpm) showed the best result. Besides that, the feed control factor (B) provided the best result at the level 3 (0.2 mm/rev). On the other hand, the depth of cut control factor (C) showed the best results at the level 3 (0.7 mm). There were also no conflicts happening in determining the optimal spindle speed, feed rate and depth of cut while the criteria of the largest response and highest S/N ration were followed. (Table 6) Thus,
Cutting Speed (A) at level 3 (1200 rpm)
Feed (B) at level 3 (0.2 mm/rev)
Depth of cut (C) at level 3 (0.7 mm)

Table 4 Experimental result for MRR

Exp No.	Spindle Speed (rpm) (A)	FEED (mm/rev) (B)	DOC (mm) (C)	Weight Before Operation (gm)	Weight After Operation(gm)	Weight Diff. (gm)	Time(sec)	volume(mm3)	MRR(mm3/min)
1	800	0.15	0.5	2839	2784	55	33.05	6997.455471	12703.39874
2	800	0.18	0.6	2782	2716	66	28	8396.946565	17993.45692
3	800	0.2	0.7	2776	2699	77	25.55	9796.437659	23005.33305
4	1000	0.15	0.6	2772	2706	66	27.15	8396.946565	18556.78799
5	1000	0.18	0.7	2820	2743	77	23.45	9796.437659	25065.51213
6	1000	0.2	0.5	2810	2755	55	21	6997.455471	19992.72992
7	1200	0.15	0.7	2901	2824	77	22.95	9796.437659	25611.60172
8	1200	0.18	0.5	2920	2865	55	19.42	6997.455471	21619.32689
9	1200	0.2	0.6	2935	2869	66	17.45	8396.946565	28872.02257

Table 5 Experimental result for Ra

Exp. No.	Spindle Speed (rpm)	Feed (mm/rev.)	Depth of Cut (mm)	Ra (µm)
1	800	0.1	0.3	0.53
2	800	0.12	0.4	0.67
3	800	0.14	0.5	0.29
4	1000	0.1	0.4	0.80
5	1000	0.12	0.5	0.77
6	1000	0.14	0.3	0.25
7	1200	0.1	0.5	1.50
8	1200	0.12	0.3	1.20
9	1200	0.14	0.4	1.25

Exp. No.	Spindle Speed (rpm)	Feed (mm/rev)	Depth of cut (mm)	MRR(mm3/min)	SNMRR
1	800	0.15	0.5	12703.39874	82.0784
2	800	0.18	0.6	17993.45692	85.10229
3	800	0.2	0.7	23005.33305	87.23657
4	1000	0.15	0.6	18556.78799	85.37006
5	1000	0.18	0.7	25065.51213	87.98153
6	1000	0.2	0.5	19992.72992	86.01744
7	1200	0.15	0.7	25611.60172	88.16873
8	1200	0.18	0.5	21619.32689	86.69684
9	1200	0.2	0.6	28872.02257	89.20954

Table 6 S/N ratio for material removal rate (MRR)

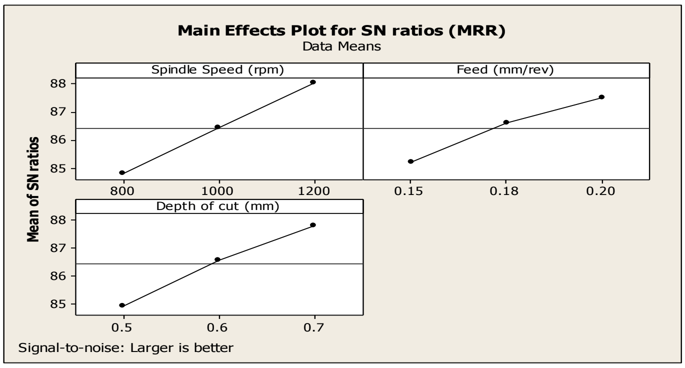

Figure 4 Main effects plot for SN ratios (MRR)

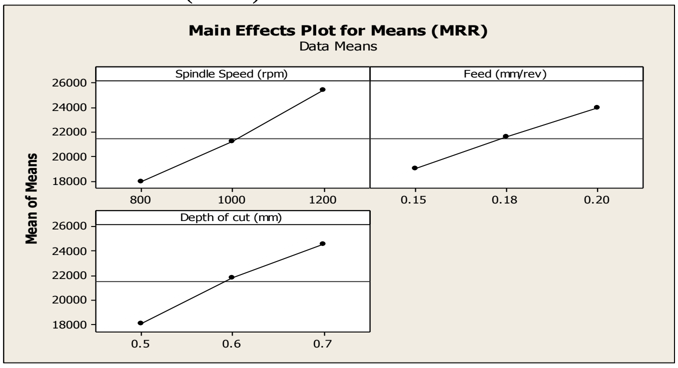

Figure 5 Main effects plot for means (MRR)

2) Surface roughness (Ra):

The-smaller-the-better characteristic was used to determine the smallest surface roughness (R_a) that would be the ideal situation for this study. Meanwhile, the larger S/N ration would be projected as the best response given in the machine set-up system which would be the ideal situation. The graphs in Figure 6 & 7 are used to determine the optimal set of parameters form this experimental design. Form the graphs, the control factor of Spindle Speed (A) at level 1 (800 rpm) show the best result. On the other hand, the feed control factor (B) provides the best result at the level 3 (0.14 mm/rev). Meanwhile, the depth of cut control factor (C) gives the best results at the level 1 (0.3 mm). There are no conflicts in determining the optimal depth of cut, spindle speed and feed rate and the criteria of the lowest response and highest S/N ration were followed (Table 7). Thus, the optimized combination of levels for all the three control factors from the analysis which provides the best surface finish was found to be

Cutting Speed (A) at level 1 (800 rpm)
Feed (B) at level 3 (0.14 mm/rev)
Depth of cut (C) at level 1 (0.3 mm)

Table 7 S/N ratio for surface roughness (RA)

Exp. No.	Spindle Speed (rpm)	Feed (mm/rev.)	Depth of Cut (mm)	Ra	SNRa
1	800	0.10	0.3	0.53	5.5145
2	800	0.12	0.4	0.67	3.4785
3	800	0.14	0.5	0.29	10.7520
4	1000	0.10	0.4	0.80	1.9382
5	1000	0.12	0.5	0.77	2.2702
6	1000	0.14	0.3	0.25	12.0412
7	1200	0.10	0.5	1.50	-3.5218
8	1200	0.12	0.3	1.20	-1.5836
9	1200	0.14	0.4	1.25	-1.9382

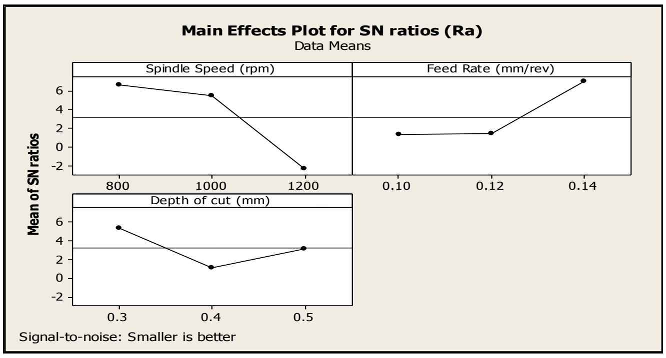

Figure 6 Main effects plot for SN ratio (surface roughness)

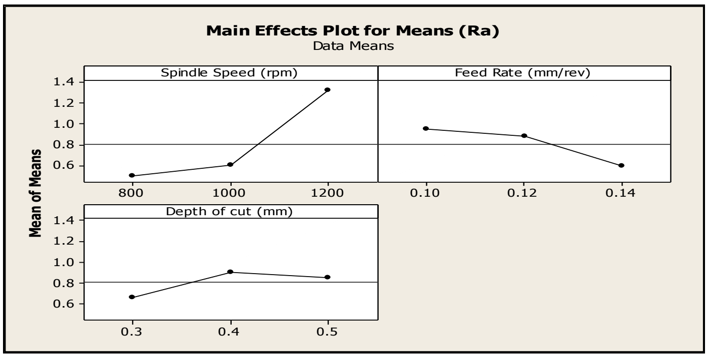

Figure 7 Main effects plot for means (surface roughness)

B. ANALYSIS OF VARIANCE (ANOVA)

1) Material removal rate

Table 8 and Figure 8 shows the percent effect of each of each parameter on the Material Removal Rate. It is illustrated that Spindle Speed has the most significant effect on the output response (MRR). Other significant parameters are, in turn, depth of cut and feed. Graphical representation of the contribution of each parameter can be easily understood by Pie Chart. Table 9 and Figure 9 shows the percent effect of each of each parameter on the Surface Roughness. It is illustrated that Spindle Speed has the most significant effect on the output response (Ra). Other significant parameters are, in turn, feed, depth of cut.

Graphical representation of the contribution of each parameter can be easily understood by Pie Chart.

D. Validation

Validation of result is an important part of project work. We have predicted Performance characteristics by two different methods as Prediction by Taguchi Method and Prediction by Regression Analysis. Three confirmations experiments also done to verify the predicted values of Performance characteristics and compared it with predicted value.

1) For Material Removal Rate (MRR)

- Prediction by Taguchi Method

For the optimal condition of process parameters Cutting Speed (A) at level 3 (1200 rpm) Feed (B) at level 3 (0.2 mm/rev) and Depth of cut (C) at level 3 (0.7 mm) value of MRR can be predicted by following equation as

$$MRR333 = \bar{A}3 + \bar{B}3 + \bar{C}3 - (2 * T)$$

Here $\bar{A}$ 3 is average of mean at level 3 of MRR
$\bar{B}$3 is average of mean at level 3 of MRR
$\bar{C}$3 is average of mean at level 3 of MRR
T is average of mean of MRR for all 9 experiments.

so, MRR333 = 25368 + 23957 + 24561 - (2 * 21491.13)
= 30903 mm3/min

- Prediction by Regression Analysis

For the optimal condition of process parameters Cutting Speed (A) at level 3 (1200 rpm) Feed (B) at level 3 (0.2 mm/rev) and Depth of cut (C) at level 3 (0.7 mm) value of MRR can be predicted by following regression equation as :

MRR333 = - 34023 + 18.7 Spindle Speed (rpm) + 98943 Feed (mm/rev) + 32278 Depth of cut (mm)
= - 34023 + 18.7 * 1200 + 98943 * 0.20 + 32278 * 0.7
= 30800.2 mm3/min

- Comparison of results

Table 11 shows value of Material Removal Rate (MRR) of optimal combination of process parameters by different methods. Value of MRR from the confirmation test is differing by less than 2 % of the prediction by Taguchi Method. Also Figure 10 shows a graphical representation of comparison by all three methods

Table 8: ANOVA for material removal rate (MRR)

Source	DF	SS	MS	F	P	% Contribution
Spindle Speed (rpm)	2	84000751	42000375	35.32	0.028	44.9550894
Feed (mm/rev)	2	37512479	18756240	15.77	0.06	20.0757354
Depth of cut (mm)	2	62963577	31481788	26.48	0.036	33.696523
Error	2	2378012	1189006			
Total	8	186854819				

Table 9: ANOVA for Surface Roughness (Ra)

Source	DF	SS	MS	F	P	% Contribution
Spindle Speed (rpm)	2	1.18860	0.59430	105.50	0.009	78.95575927
Feed (mm/rev	2	0.20447	0.10223	18.15	0.052	13.58243656
Depth of cut (mm)	2	0.10107	0.05053	8.97	0.100	6.713830211
Error	2	0.01127	0.00563			
Total	8	1.50540				

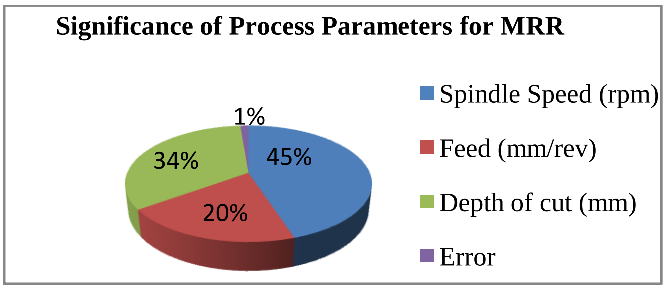

Figure 8: Significance of process parameters for MRR

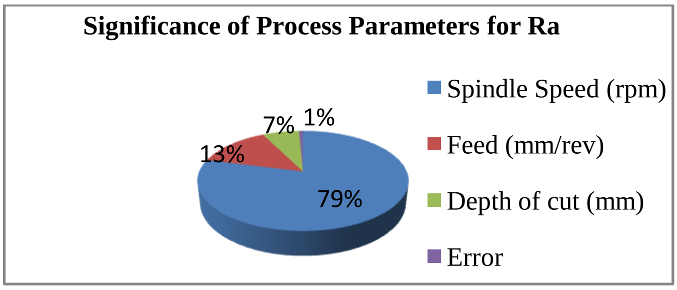

Figure 9: Significance of process parameters for Ra

- Confirmation Experiment Result

Table 10: Result of confirmation experiment (MRR)

Exp. No.	Spindle Speed (rpm) (A)	FEED (mm/rev)(B)	DOC (mm) (C)	Weight Before Operation (gm)	Weight After Operation (gm)	Weight Diff.(gm)	Time (sec)	Volume (mm3)	MRR (mm3/min)
1	1200	0.2	0.7	2930	2806	124	31.17	15770	30350.2
2	1200	0.2	0.7	2772	2653	119	29.8	15139	30480.6
3	1200	0.2	0.7	2831	2704	127	31.87	16457	30410.3

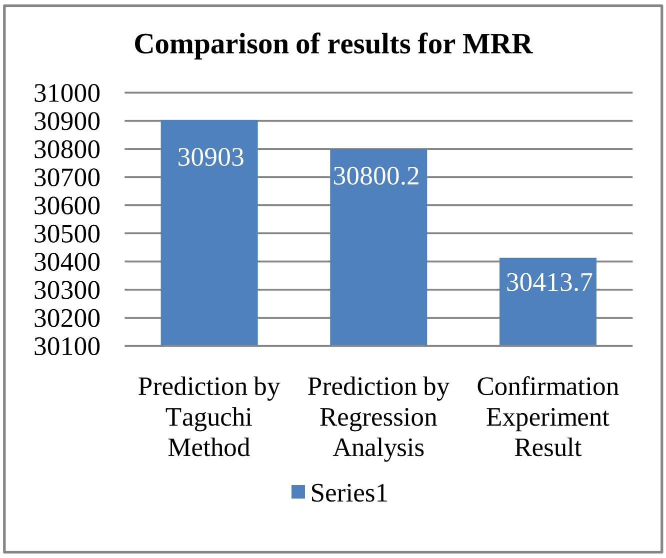

Figure 10: Comparison of results for MRR

Table 11: Comparison of results (MRR)

Method	MRR(mm3/min)
Prediction by Taguchi Method	30903
Prediction by Regression Analysis	30800.2
Confirmation Experiment Result	30413.7

2) For Surface Roughness (Ra)

- Prediction by Taguchi Method

For the optimal condition of process parameters Cutting Speed (A) at level 1 (800 rpm) Feed (B) at level 3 (0.14 mm/rev) Depth of cut (C) at level 1 (0.3 mm) value of Ra can be predicted by following equation as :

$$Ra131 = \bar{A}1 + \bar{B}3 + \bar{C}1 - (2 * T)$$

Here $\bar{A}1$ is average of mean at level 1 of Ra
$\bar{B}3$ is average of mean at level 3 of Ra
$\bar{C}1$ is average of mean at level 1 of Ra
$\bar{T}$ is average of mean of Ra for all 9 experiments.

Ra131= 0.4967+0.5967 + 0.6600 - (2 * 0.8066)
= 0.1402

- Prediction by Regression Analysis

For the optimal condition of process parameters cutting Speed (A) at level 1 (800 rpm) Feed (B) at level 3 (0.14 mm/rev) Depth of cut (C) at level 1 (0.3 mm) value of Ra can be predicted by following regression equation as :

Ra_{131} = -0.59 + 0.00205 Spindle Speed (rpm) - 8.66667 Feed Rate (mm/rev) +0.966667 Depth of cut (mm)
= -0.59 + (0.00205 * 800) - (8.66667 * 0.14) + (0.966667 * 0.3)
= 0.1726 µm

- Confirmation Experiment Result

Table 12: result of confirmation experiment (Ra)

Exp. No.	Ra (µm)
1	0.15
2	0.16
3	0.15
Avg.	0.1533

- Comparison of results

Table 13 shows value of Surface Roughness (Ra) of optimal combination of process parameters by different methods. Value of Ra from the confirmation test is differing by less than 10 % of the prediction by Taguchi Method. Also Figure.11 shows a graphical representation of comparison by all three methods.

Table 13: comparison of results (Ra)

Method	Ra(µm)
Prediction by Taguchi Method	0.1402
Prediction by Regression Analysis	0.1726
Confirmation Experiment Result	0.1533

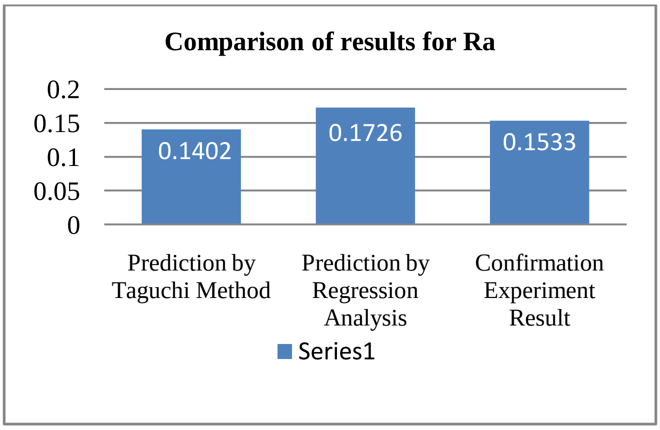

Figure 11: Comparison of results for **Ra**

V. CONCLUSION:

The present project work was carried out to study the effect of process parameter such as spindle speed, feed and depth of cut on the performance parameter such as material removal rate and surface roughness. The following conclusion has been drawn from the study. Material removal rate is mainly affected by spindle speed (45%)and depth of cut (34%) while surface roughness is mainly affected by spindle speed (79%).The least significant parameter for material removal rate is feed (20%) and for surface roughness is depth of cut(7%). Linear regression model and Taguchi mean estimation method is used to predict material removal rate and surface roughness. The process parameters considered in the experiments are optimized to attain maximum material removal rate. The best combination of process parameters for turning within the selected range is as follow: Cutting Speed 1200 rpm, Feed 0.2 mm/rev, Depth of cut 0.7 mm. The process parameters considered in the experiments are optimized to attain minimum Surface Roughness (Ra). The best combination of process parameters for turning within the selected range is Cutting Speed 800 rpm, Feed 0.14 mm/rev Depth of cut 0.3 mm.

VI. FUTURE SCOPE

It can be also done for L27 orthogonal array. We can also do for more process parameters such as nose radius and rake angle of cutting tool which we have taken constant. On economical aspect of view it can be also done for it.

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