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Optimization of Machining Parameters for Turning using Taguchi Approach

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***Abstract:** Modern manufacturers, seeking to remain competitive in the market, rely on their Manufacturing engineers and production personnel to quickly and effectively set up manufacturing processes for new products. This paper presents the single response optimization of turning parameters for Turning on EN8 Steel. Experiments are designed and conducted based on Taguchi's L9 Orthogonal array design. This paper discusses an investigation into the use of Taguchi parameter Design optimize the Surface Roughness and Tool tip temperature in turning operations using single point carbide Cutting Tool. The Analysis of Variance (ANOVA) is employed to analyze the influence of Process Parameters during Turning. The useful results have been obtained by this research for other similar type of studies and can be helpful for further research works on the Tool life.*

***Keywords:** ANOVA, EN8, Optimization, Surface Roughness, Turning.*

I. INTRODUCTION

Turning is one of the most basic machining processes. The part is rotated while a single point cutting tool is moved parallel to the axis of rotation. Turning can be done on the external surface of the part as well as internally (boring). The starting material is generally a work piece generated by other processes such as casting, forging, extrusion, or drawing. Turning can be done manually, in a traditional form of lathe, which frequently requires continuous supervision by the operator, or by using a Computer-controlled and automated lathe which does not. This type of machine tool is referred to as having computer numerical control, better known as CNC [1] and is commonly used with many other types of machine tools besides the lathe. The turning process can be of different types such as straight turning, taper turning, profiling or external grooving. Turning process can produce various shapes of materials such as straight, conical, curved, or grooved work pieces. In general, turning uses simple single-point cutting tools. Each group of work piece materials has an optimum set of tools angles which have been developed through the years. In turning process, parameters such as cutting tool geometry and materials, number of passes, depth of cut for each pass, the depth of cut, feed rates, cutting speeds as well as the use of cutting fluids will impact the production costs, MRRs, tool lives, cutting forces, and the machining qualities like the surface roughness, the roundness of circular and dimensional deviations of the product.[2] Basically, tool life, cutting force, and surface roughness are strongly correlated with cutting parameters such as cutting speed, feed rate, and depth of cut. Proper selection of the cutting parameters can obtain a minimum cost, maximum MRRs, longer tool life, a lower cutting force, and better surface roughness.

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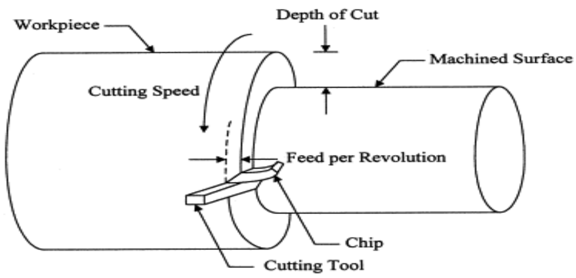

Fig 1: Representation of turning process

II. LITERATURE REVIEW

M.Madic et.al [3] Presented an approach by coupling artificial neural network (ANN) and improved harmony search algorithm (IHSA) to determine the optimum cutting parameter settings for minimizing surface roughness when turning of polyamide material. An ANN model surface roughness was developed in terms of cutting speed, feed rate, depth of cut, and tool nose radius using the data from the turning experiment conducted according to Taguchi's L27 orthogonal array. The optimal cutting parameter settings were determined by applying the IHSA to the developed ANN surface roughness model. Mr. Manoj Kumar Sahoo [4] reported the optimization of turning process by the effects of machining parameters applying Taguchi methods. Three machining parameters i.e., Spindle speed, Feed rate and Depth of cut. Experiments were done by varying one parameter and keeping other two fixed so maximum value of each parameter was obtained. Taguchi orthogonal array is designed with three levels of turning parameters with the help of software Minitab 16. Dr.S.S.Chaudhari et.al [5] investigated a single characteristic response optimization model based on Taguchi Technique was developed to optimize process parameters, such as speed, feed, depth of cut, and nose radius of single point cutting tool.

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Taguchi's L9 orthogonal array is selected for experimental planning. The experimental result analysis showed that the combination of higher levels of cutting speed, depth of cut and lower level of feed is essential to achieve simultaneous maximization of material removal rate and minimization of surface roughness. Kanase Tanaji. S and Jadhav D. B. [6] Conducted experiments on, a CNC turning centre for machining the different workpiece material with different types of cutting tool inserts with a set of values for the given parameters. The process would be repeated for different values of the parameters while keeping the other constant. Taguchi method is used for finding the optimized solution. Ajay Mishra and Dr. Anshul Gangele [7] used Taguchi techniques to find out the optimum tool flank wear width in turning operation of AISI 1045 Steel. A L9 orthogonal array, S/N ratios and ANOVA are used to study the performance characteristics of cutting speed, feed rate and depth of cut as turning parameters with tool flank wear width as response variable. The result of the analysis show that the selected machining parameters affect significantly the tool flank wear width of Tungsten Carbide cutting tool while machining AISI 1045 steel and also indicate that the cutting speed is the most influencing parameter out of the three parameters under study. Harsimran Singh Sodhi and Harjot Singh [8] Discusses an investigation into the use of Taguchi Parameter Design for optimizing surface roughness generated by a conventional lathe. Control parameters being consider in this paper are cutting speed, feed rate and depth of cut. After experimentally turning sample workpieces using the selected orthogonal array and parameters, this study expected to produce an optimum combination of controlled parameter for the surface roughness. Prof. Atul dhale and Fahim khan [9] proposed AE as non-contact and indirect technique for in-process surface roughness assessment in turning. Three cutting conditions dry cut, cutting with water as coolant and normal coolant were used. The material used in study is EN8. Three cutting parameters namely feed rate, depth of cut, cutting speed are optimized with consideration with surface roughness. Taguchi method is used find optimal cutting parameters for surface roughness (Ra) in turning. Regression models are developed and validated to predict the surface roughness and AE Signal value. H. K. Dave et. Al [10] presented an experimental investigation of the machining characteristics of different grades of EN materials in CNC turning process using TiN coated cutting tools. They focused on the analysis of optimum cutting conditions to get the lowest surface roughness and maximum material removal rate in CNC turning of different grades of EN materials by Taguchi method. Optimal cutting parameters for each performance measure were obtained employing Taguchi techniques. The orthogonal array, signal to noise ratio and analysis of variance were employed to study the performance characteristics in dry turning operation. ANOVA has shown that the depth of cut has significant role to play in producing higher MRR and insert has significant role to play for producing lower surface roughness. M. Adinarayana et.al [11] presented the multi response optimization of turning parameters for turning on AISI 4340 Alloy Steel. Experiments are designed and conducted based on Taguchi's L27 Orthogonal array design. they discusses an investigation into the use of Taguchi parameter Design and Regression analysis to predict and optimize the Surface Roughness, Metal Removal Rate and Power Consumption in turning operations using CVD Cutting Tool. The Analysis of Variance (ANOVA) is employed to analyze the influence of Process Parameters during Turning. This paper also remarks the advantages of multi-objective optimization approach over the single-objective one. E. Daniel Kirby [12] discusses an investigation into the use of Taguchi Parameter Design for optimizing surface roughness generated by a CNC turning operation. This study utilizes a standard orthogonal array for determining the optimum turning parameters, with an applied noise factor. Controlled factors include spindle speed, feed rate, and depth of cut; and the noise factor is slightly damaged jaws. The noise factor is included to increase the robustness and applicability of this study. After experimentally turning sample workpieces using the selected orthogonal array and parameters, this study produced a verified combination of controlled factors and a predictive equation for determining surface roughness with a given set of parameters Kamal Hassan et. al [13] Machining of medium Brass alloy is very difficult. There are a number of parameters like cutting speed, feed and depth of cut etc. which must be given consideration during the machining of medium Brass alloy. This study investigates the effects of process parameters on Material Removal Rate (MRR) in turning of C34000. The single response optimization problems i.e. optimization of MRR is solved by using Taguchi method. The optimization of MRR is done using twenty seven experimental runs based on L'27 orthogonal array of the Taguchi method are performed to derive objective functions to be optimized within the experimental domain When the MRR is optimized alone the MRR comes out to be 8.91. The optimum levels of process parameters for simultaneous optimization of MRR have been identified. Optimal results were verified through confirmation experiments Vladimir Aleksandrovich Rogov and Ghorbani Siamak [14] investigated the influence of cutting parameters on surface roughness and natural frequency in turning of aluminum alloy AA2024. The experiments were performed at the lathe machine using two different cutting tools made of AISI 5140 and carbide cutting insert coated with TiC. Turning experiments were planned by Taguchi method L9 orthogonal array. Three levels for spindle speed, feed rate, depth of cut and tool overhang were chosen as cutting variables. The obtained experimental data has been analyzed using signal to noise ratio and analysis of variance. Ali Riza Motorcu [15] Studied on surface roughness in the turning of AISI 8660 hardened alloy steels by ceramic based cutting tools was investigated in terms of main cutting parameters such as cutting speed, feed rate, depth of cut in addition to tool's nose radius, using a statistical approach. Machining tests were carried out with PVD coated ceramic cutting tools under different conditions. An orthogonal design, signal-to-noise ratio and analysis of variance were employed to find out the effective cutting parameters and nose radius on the surface roughness. The obtained results indicate that the feed rate was found to be the dominant factor among controllable factors on the surface roughness, followed by depth of cut and tool's nose radius.D.

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Philip Selvaraj and P. Chandramohan [16] discussed the dry turning of AISI 304 Austenitic Stainless Steel (ASS). They studied the influence of cutting parameters like cutting speed, feed rate and depth of cut on the surface roughness of austenitic stainless steel during dry turning. A plan of experiments based on Taguchi's technique has been used to acquire the data. An orthogonal array, the signal to noise (S/N) ratio and the analysis of variance (ANOVA) are employed to investigate the cutting characteristics of AISI 304 austenitic stainless steel bars using TiC and TiCN coated tungsten carbide cutting tool.

III. EXPERIMENTAL WORKS

In this study, Taguchi method is used for single characteristics optimization has been used to establish correlation between the independent variables therefore; the experiments were performed according to a Taguchi design of experiments.

3.1 Work material & cutting tool

The work material selected in this investigation was EN8. The chemical composition of the EN8 tool steel includes: 0.35-0.45 % C, 0.60-1.00%Mn, 0.060%S, 0.060%P, 0.05-0.35%Si. Commercially available EN8 round bar of dia. 40 mm was used as wprkpiece material and turned up to 30mm diameter. A commercially available single point carbide cutting tool was used as cutting tool material.

3.2 Design of experiments

Experiments were designed using Taguchi method which uses an OA to study the entire parametric space with a limited number of experiments. In present research two parameter (factors) chosen such as speed and depth of cut. All of them were set at three different levels. (See table 1)

Table 1: Level values of input parameters

Sr. No.	Parameters	Unit	Level 1	Level 2	Level 3
1	Speed	RPM	105	275	460
2	Depth of cut	mm	0.5	1	1.5

Selection of a particular OA is based on the number of levels of various factors. Here, 4 parameters each at 3 levels, therefore Degree of Freedom (DOF) can be calculated as, Eq.1 [17]

$$(DOF)R = P \times (L - 1) \qquad (1)$$

P = number of factors, L = number of levels

$$(DOF)R = 4 \times (3 - 1) = 8$$

Total DOF of OA should be greater than or equal to the total DOF required for the experiment. [18], here 9 > 8 hence L9 (3^4) OA is selected (See Table 2). Each machining parameter is assigned to a column of OA and 9 machining parameter combinations are designed. The response variables chosen for the present investigation are: surface roughness and tool tip temperature. The "smaller-the-better" quality characteristic has been used for calculating the signal to noise (S/N) ratio of both quality characteristic. See Eq.2. **[**19]

$$MSD_{LB} = \frac{1}{R} \sum_{J=1}^{R} (Y_J^2) \qquad (2)$$

Where y_j is the response value for i_{th} experiment

Table 2: L9 Design matrix

Expt. No	Parameter1	Parameter2
E 1	105	0.5
E 2	105	1
E 3	105	1.5
E 4	275	0.5
E 5	275	1
E 6	275	1.5
E 7	460	0.5
E 8	460	1
E 9	460	1.5

3.3 Experimental planning

Experiments were conducted using an HI-MAC LX165 as per L9 OA combinations & each experiment were repeated two times for getting reliable database i.e.9×2 total 18 experiments conducted. Figure 2 shows the experimental setup for present study. Surface roughness was measured using MITUTOYO made surf tester and tip temperature was measured using HTC made thermometer for all 18 specimens as shown in Fig.2 and 4.

IV. EXPERIMENTAL RESULTS AND DISCUSSION

4.1 Effect of process parameters on surface roughness

In order to see the effect of process parameters on the MRR, experiments were conducted using L9 OA (Table 2). The experimental data and S/N ratios is given in Table 3**.** According to response table 4, graphs were generated shown in Figure 3 which shows that the surface roughness decreases with the increase of speed and also increases in depth of cut there is decrement in surface roughness.

Table 3: Mean values and S/N ratios of observed results

Ex. No	Surface roughness Value (Ra)			S/N Ratio	Tool Tip temperature (⁰c)			S/N Ratio
	Trial 1	Trial 2	Average		Trial 1	Trial 2	Average	
1	6.641	6.638	6.6395	-16.4427	37.1	37.95	37.525	-31.4864
2	8.273	8.182	8.2275	-18.3054	41.9	42.4	42.15	-32.496
3	6.150	6.242	6.196	-15.8422	44.9	45.02	44.96	-33.0565
4	5.217	5.011	5.114	-14.1752	41.5	41.9	41.7	-32.4027
5	7.112	7.125	7.1185	-17.0478	45.3	45	45.15	-33.0932
6	5.141	5.246	5.1935	-14.3092	48.2	48.5	48.35	-33.6879
7	5.316	5.245	5.2805	-14.4535	42.8	42.73	42.765	-32.6218
8	3.416	3.328	3.372	-10.5578	49.1	49.3	49.2	-33.8393
9	3.798	3.695	3.7465	-11.4725	61.85	62.39	62.12	-35.8646

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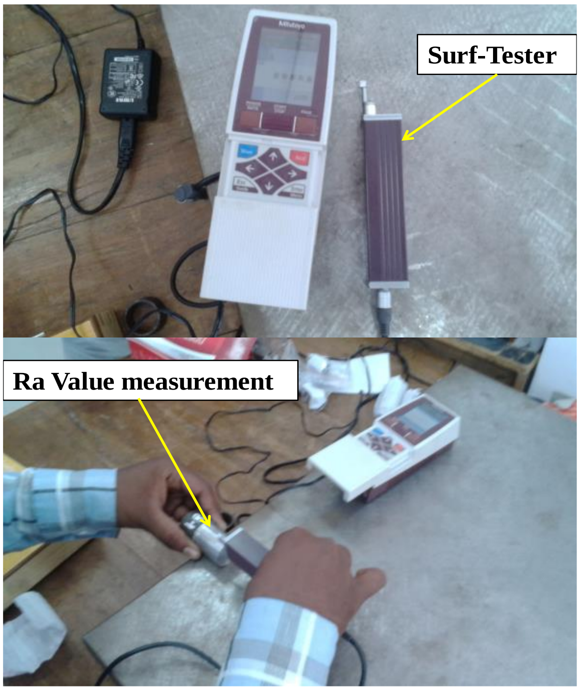


Fig.2: Set-up for Surface roughness (Ra) value measurement

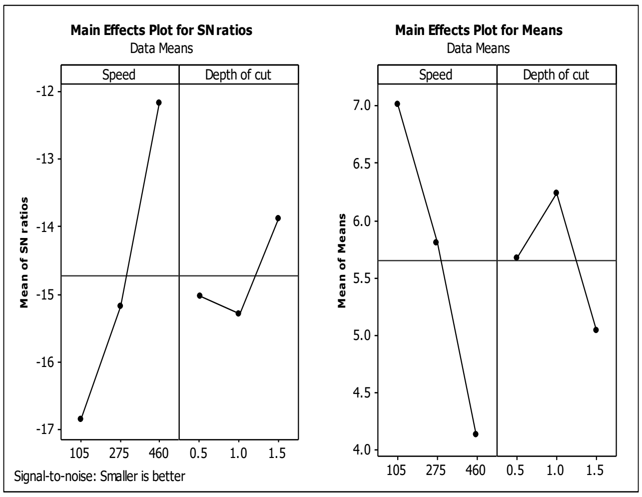
4.1.1.2 Selection of optimal levels

In order to study the significance of the process variables towards surface roughness, analysis of variance (ANOVA) was performed. From these tables, it is clear that speed and depth of cut significantly affect both the surface roughness value.

The ranks and the delta values show that speed have the greatest effect on surface roughness and are followed by depth of cut. As surface roughness is the "smaller is better" type quality characteristic, it can be seen from Figure 4 that the third level of speed(A3) and second level of depth of cut (B2) provide best value of surface roughness. The S/N data analysis suggests the same levels of the variables (A3 and B2) as the best levels.

Table 4: Mean values and S/N ratios of observed results

Mean data				S/N data	
Levels	Speed	Depth of cut		Speed	Depth of cut
1	7.021	5.678		-16.86	-15.02
2	5.809	6.239		-15.18	-15.30
3	4.133	5.045		-12.16	-13.87
Delta	2.888	1.194		4.70	1.43
Rank	1	2		1	2



ANOVA for Ra

Parameter	Degree of freedom	Seq. sum of square	Adj.sum of square	Adj. Mean square	F	P	% Contribution (P)
Speed	2	12.618	12.618	6.309	5.30	0.075	64.65
Depth of cut	2	2.141	6.239	1.070	0.90	0.476	10.96
Error	4	4.763	4.763	1.191			24.39
Total	4	19.522					100.00
S =1.09118,		R. Sq =75.60%			R. Sq(Adj) =51.21%		

4.2 Effect of process parameters on tool tip temperature

In order to see the effect of process parameters on the Tool tip temperature, experiments were conducted using L9 OA (Table 2). The experimental data and S/N ratios is given in Table 3**.** According to response table 6, graphs were generated shown in Figure 5 which shows that the Tool tip temperature increases with the increase of speed and depth of cut while decreases when both value are at level one.

4.1.1.2 Selection of optimal levels

In order to study the significance of the process variables towards Tool tip temperature, analysis of variance (ANOVA) was performed. From these tables, it is clear that speed and depth of cut significantly affect both the Tool tip temperature value. The ranks and the delta values show that depth of cut has the greatest effect on surface roughness and are followed by speed. As Tool tip temperature is the "smaller is better" type quality characteristic, it can be seen from Figure 5 that the first level of speed (A1) and first level of depth of cut (B1) provide best value of Tool tip temperature. The S/N data analysis suggests the same levels of the variables (A1 and B1) as the best levels.

Table 6: Mean values and S/N ratios of observed results

Mean data				S/N data	
Levels	Speed	Depth of cut		Speed	Depth of cut
1	41.55	40.66		-32.35	-32.17
2	45.07	45.50		-33.06	-33.14
3	51.36	51.81		-34.11	-34.20
Delta	9.82	11.15		1.76	2.03

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Rank	2	1		2	1

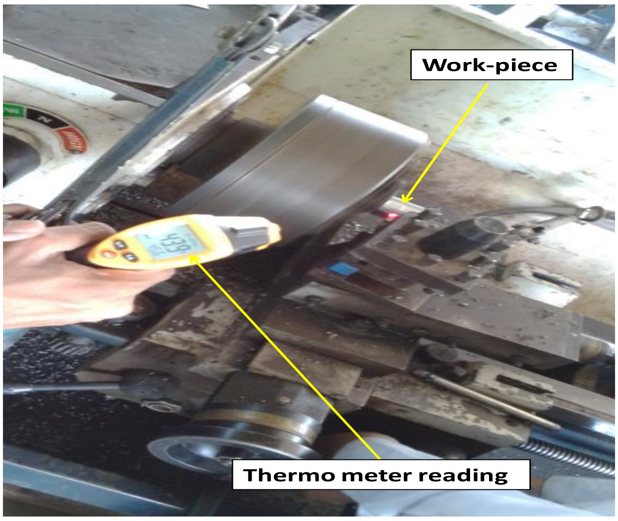
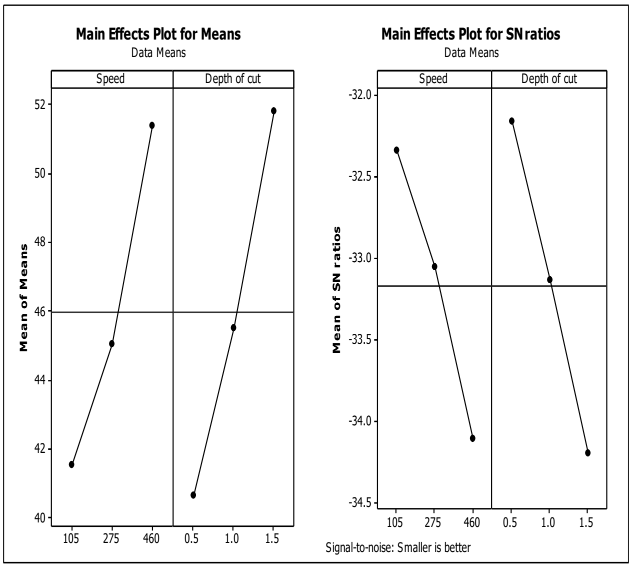


Fig.4: Set-up for Temperature measurement



ANOVA for Temp.							
Parameter	Degree of freedom	Seq. sum of square	Adj.sum of square	Adj. Mean square	F	P	% Contribution (P)
Speed	2	148.40	148.40	74.20	5.19	0.077	37.75
Depth of cut	2	187.46	187.46	93.73	6.56	0.055	47.70
Error	4	57.17	57.17	14.29			14.55
Total	4	393.02					100.00
S = 3.78054		R. Sq = 85.54%			R. Sq(Adj) =70.91%		

V. CONCLUSIONS

This paper presents the application of single characteristics optimization approaches for turning processes. These approaches utilized in many fields to optimize the single and multi performance characteristics efficiently. Turning is one of the most basic machining processes in traditional manufacturing process. In the present study two important points ware drawn as (1) for surface roughness optimum combination find out as A3, B2 (2) for tool tip temperature optimum combination was A1, B1.which gives best results.

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