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PROCESS PARAMETER OPTIMIZATION IN LATHE TURNING OPERATION TO IMPROVE THE SURFACE ROUGHNESS AND REDUCE THE CUTTING FORCE USING TAGUCHI METHOD

SUBHABRATA BANERJEE
Department of Mechanical Engineering Dr. Sudhir Chandra Sur Degree Engineering College, Kolkata, India, subhokingrules@gmail.com

SUMON KUNDU
Department of Mechanical Engineering Dr. Sudhir Chandra Sur Degree Engineering College, Kolkata, India 95kundusumon@gmail.com

SUPRATIM CHOUDHURY
Department of Mechanical Engineering Dr. Sudhir Chandra Sur Degree Engineering College, Kolkata, India supratim.choudhury3@gmail.com

ARPITA CHATTERJEE
Department of Mechanical Engineering Dr. Sudhir Chandra Sur Degree Engineering College, Kolkata, India arpitachat.mckv@gmail.com

ABSTRACT

This paper represents an experimental study of Process Parameter Optimization to Improve the Surface Roughness generated and Reduction of the Cutting Force used in Lathe Turning Operation on a mild steel job and optimization of machine parameters by Taguchi Method. The Surface Roughness Parameter is the Response Surface Methodology. For developing mathematical model for predicting surface roughness parameter and cutting forces, the three level central composite design is employed.

Taguchi method is a statistical approach in optimizing the process parameters used in quality control process to improve the quality of the manufactured component. In the following analysis three parameters namely speed, feed and depth of cut were considered. Experiment was conducted considering a suitable orthogonal array. Cutting force and surface roughness were measured and Signal to Noise ratio was calculated. Analyzing the graph provided us with the optimum value.

INTRODUCTION

The growth of the company mainly depends upon the quality of the product it manufactures. Material and the process parameters determine the product quality. Optimization technique plays a major role to increase the quality of the product. Grey relational analysis (GRA) and Taguchi Method has been used by many researchers for optimizing the machining parameters in different types of machining operation to improve the quality of product.

The objective of the paper is to determine the optimal level of process parameter in lathe turning operation using Taguchi method approach. The work-piece was of mild steel (EN8 grade) of diameter mm and length mm. The cutting tool used was high speed steel (HSS). Signal-to-Noise ratio analysis in Taguchi method was applied to obtain the optimal process parameter.

RECENT STATUS

Some study reported that the optimization of CNC turning operation parameters for Copper using the Grey relational analysis method. In turning process parameters such as cutting tool geometry and materials, depth of cut, feed rates, cutting speeds as well as the use of cutting fluids will impact the MRR and machining properties like surface roughness. The controllable input parameters were Speed (RPM), Feed (mm/rev) and Depth of Cut (mm) (*Rohit Anil Pathak*).

Lastly he concluded that after identifying the most influential parameters, the final phase is to verify the Speed, Feed and Depth of Cut by conducting the confirmation experiments. The scheme 27 is an optimal parameter combination of the turning process via the Grey relational analysis. Therefore, the condition scheme 27 of the optimal parameter combination of the turning process was treated as a confirmation test.

Some study reported that Taguchi Method is a statistical approach to optimize the process parameters and improve the quality of components that are manufactured. The objective of this study is to illustrate the procedure adopted in using Taguchi Method to a lathe facing operation. The orthogonal array, signal-to-noise ratio, and the analysis of variance are employed to study the performance characteristics on facing operation (*Srinivas Athreya, Dr Y.D.Venkatesh*).

Lastly he concluded that, Taguchi's Method of parameter design can be performed with lesser number of experimentations as compared to that of full factorial analysis and yields similar results. Taguchi's method can be applied for analyzing any other kind of problems as described in this paper. It is found that the parameter design of the Taguchi method provides a simple, systematic, and efficient methodology for optimizing the process parameters.

Some study reported that the effect of cutting parameters (speed, feed, depth of cut) in CNC (Computer Numerical Control) turning of AA7075 to achieve low surface roughness using tungsten carbide insert(*Ch.Maheswara Rao, K venkatasubbaiah*).

Lastly he Concluded that, From Taguchi results, the optimal combination of cutting parameters for low surface roughness was found at v1-f1-d1 i.e., speed at 1000 rpm, feed at 0.2 mm/rev and depth of cut at 0.5 mm. From ANOVA results, for achieving minimum surface roughness values, feed has high influence (F = 764.02) followed by speed (F = 0.74) and depth of cut (F = 0.53) has low influence. %Errors between experimental and regression values are within the acceptable range (±7).

Some study reported that the optimal set of process parameters such as current, pulse ON and OFF time in Electrical Discharge Machining (EDM) process to identify the variations in three performance characteristics such as rate of material removal, wear rate on tool, and surface roughness value on the work material for machining Mild Steel IS 2026 using copper electrode. Based on the experiments conducted on L9 orthogonal array, analysis has been carried out using Grey Relational Analysis, a Taguchi method (*Raghuram S, Thirupathi k, Paneerselvam T, Santosh S*).

Lastly he concluded that, The optimal parameters combination was determined as A3B2C1 i.e. pulse current at 26A, pulse ON time at 55µs and pulse OFF time at 5µs. The predicted results were checked with experimental results and a good agreement was found. This work demonstrates the method of using Taguchi methods for optimizing the EDM parameters for multiple response characteristics.

Some study reported that the optimization of the surface roughness using the Taguchi technique to assess the machinability of the AISI 316Ti steel with PVD coated carbide inserts under different cooling conditions such as dry, conventional (wet) and cryogenic cooling with liquid nitrogen (LN2). Based on the Taguchi L9 (33) orthogonal-array design, the machinability tests were made utilizing a CNC lathe machine. Test parameters including the cutting speed, the cooling condition and the feed rate were taken and then the surface roughness (Ra) was measured to obtain the machinability indicator. An analysis of variance was performed to determine the importance of the input parameters for the surface roughness. The process parameters were optimized by taking the Taguchi technique into consideration (*Murat Sarýkaya*).

Lastly he concluded that this study focused on the influences of the process parameters such as the cooling condition, the feed rate and the cutting speed on the surface roughness (Ra) in the turning of the AISI 316Ti stainless steel and an optimization was achieved on the basis of the Taguchi method. Cryogenic cooling using liquid nitrogen (LN2) was applied from within a modified tool holder. The Taguchi S/N ratio was utilized with the smaller-the-better approach to obtain the optimum values. An analysis of variance was performed to define the importance of the process parameters for the outputs. Based on the first order model, a mathematical model was created, namely Rapre, using the regression analysis.

SURFACE ROUGHNESS

Surface roughness is defined as the irregularities present in the surface. It is an important parameter in determining the quality of the product. Less surface roughness means, less amount of irregularities and superior product quality. In the following experimentation tally surf has been employed to determine the average surface roughness (Ra).

CUTTING FORCE

Cutting Force is required to remove the materials from the work-piece during the turning operation. So if the amount of force used during the turning can be reduced this will lead to a more efficient cutting operation.

METHODOLOGY ADOPTED

The study depends upon the methodology opted for the proceeding as it decides the way of collecting the data, manipulation, processing and display of the results finally.

1. Measurement of cutting force by using electrical strain gauge is the best technique available.
2. The machining parameters will be considered during the machining with respect to cutting forces and feed forces by predicting the cutting performance such as depth of cut, feed/rev. and speed.

EXPERIMENTAL SETUP

MATERIALS & EQUIPMENTS

The material used in this experiment is mild steel bar diameter 40mm and length is 50mm. A single sample of same material and dimension has been made. The Lathe machine is used to turn the mild steel bar manufactured by **PATHAK**. After machining the surface roughness and surface profile have been measured with the help of a portable surface roughness test. The cutting force is measured by dynamometer.

MILD STEEL BAR SPECIFICATION

E8 Standard, High Peak Steels Color coding – EN8.

EN8 is medium carbon steel usually supplied untreated having good tensile strength

EN8 is a very popular grade easily machinable in any condition and it can be further surface-hardened to produce components with increased wear resistance, typically in the range 50-55 HRC through induction processes.

I. CHEMICAL COMPOSITION

MATERIAL	MAX VALUES
Carbon	0.35-0.45%
Phosphorous	0.06% max
Manganese	0.60-1.00%
Sulfur	0.06% max
Silicon	0.05-0.35%

II. MECHANICAL PROPERTIES

Max Stress	Yield Stress, Min, Mpa	0.2% Proof Stress	Impact KCV	% Elongation	Hardness
700-850 n/mm2	465 n/mm^2 Min (up to 19mm LRS)	450 n/mm2 Min (up to 19mm LRS)	28 Joules Min (up to 19mm LRS)	16% Min 12% if cold drawn	201-255 Brinell

APPARATUS

Items	Description
Work-piece	Mild-steel (EN8 grade)
Cutting tool	High-speed steel (HSS)
Tally surf	SURFTEST (SJ-210- Series 178)
Lathe	Pathak (all gear)
Dynamometer	AKSHAR (AE-15)

EXPERIMENT DATA and ANALYSIS

TAGUCHI METHOD

Design of an experiment is an essential tool for conducting the experiment with minimum resources. Orthogonal Array is a statistical method of defining parameters that converts test areas into factors and levels. In this work, L9 Orthogonal Array design matrix is used to evaluate the process performance.

I. IDENTIFYING THE CONTROL FACTORS AND THEIR LEVELS

To conduct the experiment first of all the factors and the levels are decided, secondly based on the design and also considering the guide lines given in the operator's manual provided by the manufacturer of the lathe machine is also taken into account for further steps. Similarly the factors and their levels are shown in the table below.

FACTORS	PARAMETER	LEVEL-1	LEVEL-2	LEVEL-3
A	SPEED (rpm)	303	455	685
B	FEED (mm/rev)	0.067	0.111	0.167
C	DEPTH OF CUT(mm)	0.2	0.4	0.6

The Experimental result & analysis in the experiments are used for determining the assessment of surface roughness which is influenced by cutting parameters like sped, feed, depth of cut, shim material, tool noise radius.

II. SELECTION OF ORTHOGONAL ARRAY

To select an appropriate orthogonal array for conducting the experiments and to obtain an accurate result, we should determine the degrees of freedom positively. The same data is given below: Degrees of Freedom: 1 for Mean Value, and 9 = (3x3), two each for the remaining factors Total Degrees of Freedom: 9 The most suitable and perfect orthogonal array for experimentation purpose is L9 array as shown in Table - .As a result, a total nine experiments are to be carried out firmly and effectively.

Table – 1, Orthogonal Array (OA) L9

Experiment No.	Control Factors		
	1	2	3
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. EXPERIMENTAL DATA

According the above Array, experiments were conducted with factors and levels as mentioned in table 5.1.2. Each of the above 9 experiments were conducted. The surface roughness (Ra) and cutting forces (F) were measured using the surface roughness tester and dynamometer. The table 5.1.3 shows the measured values of surface roughness obtained from different experiments.

Table – 2, Measured Values of Surface Roughness and Cutting Forces

Sl No.	SPEED (rpm)	FEED (mm/rev)	DEPTH OF CUT (mm)	CUTTING FORCE	SURFACE ROUGHNESS
1	303	0.067	0.2	2	8.965
2	303	0.111	0.4	4	13.197
3	303	0.167	0.6	8	15.628
4	455	0.067	0.4	5	19.825
5	455	0.111	0.6	8	11.68
6	455	0.167	0.2	6	22.518
7	685	0.067	0.6	9	12.723
8	685	0.111	0.2	3	17.943
9	685	0.167	0.4	11	25.537

ANALYSIS OF THE EXPERIMENT

The above experiments were conducted based on varying the process parameters, which as a result affects the machining process to obtain the required quality characteristics and values. Quality characteristics are the response values or output values expected out of the experiments. There are nearly about 64 such quality characteristics. The most commonly used are:

1. Larger the better $-10\times\log_{10}(\sum (1/Y^2)/n)$
2. Smaller the better $-10\times\log_{10}(\sum (Y^2)/n)$
3. Nominal the best $-10\times\log_{10}(Y^2/s^2)$

As the objective of the experiment is to achieve lower surface roughness and lesser cutting force so the output must be as low as possible so smaller the better is the best suited option.

ANANLYSIS BASED ON SURFACE ROUGHNESS

I. S/N RATIO CALCULATION

Table – 3.1, S/N Ratio Calculation Based on Surface Roughness

Sl No.	SPEED (rpm)	FEED (mm/rev)	DOC (mm)	Ra (μ)	SNRA	MEAN
1	303	0.067	0.2	8.965	-19.0510	8.965
2	303	0.111	0.4	13.197	-22.4095	13.197
3	303	0.167	0.6	15.628	-23.8781	15.628
4	455	0.067	0.4	19.825	-25.9443	19.825
5	455	0.111	0.6	11.680	-21.3489	11.680
6	455	0.167	0.2	22.518	-27.0506	22.518
7	685	0.067	0.6	12.723	-22.0918	12.723
8	685	0.111	0.2	17.943	-25.0779	17.943
9	685	0.167	0.4	25.537	-28.1434	25.537

II. RESPONSE TABLES, GRAPHS & RESULT DISCUSSION

S/N Ratio has been calculated based on data of Surface Roughness and analysed the result. We got two response tables and two graphs, where one table and graph for S/N Ratio calculation and another table and graph for Mean calculation.

For S/N Ration calculation, the analysis result came in the form of response table (Table - 3.2), which was calculated by an equation applicable for smaller the better case and the graph shows the graphical output based on the analysis results. In the graph (Figure - 3.1), Speed and Feed both are directly proportional to the Mean of S/N Ratio and the DOC varies with the Mean of S/N Ratio. From graph, the maximum values of Speed, Feed and DOC was considered, but the combination of the values is not available in L9 array. So the next possible combination for the maximum values was taken.

For Mean calculation, the analysis result was in the form of response table (Table - 3.3) and the graph shows the graphical output based on the analysis results. In the graph (Figure - 3.2), Speed and Feed both are directly proportional with the Mean of Means and the DOC varies with the Mean of Means. From graph, the minimum values of Speed, Feed and DOC was considered, but the combination of the values is not available in L9 array. So the next possible combination for the maximum values was taken.

A. FOR SIGNAL TO NOISE RATIOS –

Standard deviation was subtracted from each measurement in the sample (sample mean), then the square difference obtained prior were calculated. The sample variance is written as:

S/N ratio = $-10\times\log_{10} (\sum (Y^2)/n)$

Smaller is better.

Table – 3.2, Response Table for S/N Ratio

Level	SPEED (rpm)	FEED (mm/rev)	DOC (mm)
1	-21.78	-22.36	-23.73
2	-24.78	-22.95	-25.50
3	-25.10	-26.36	-22.44
Delta	3.32	4.00	3.06
Rank	2	1	3

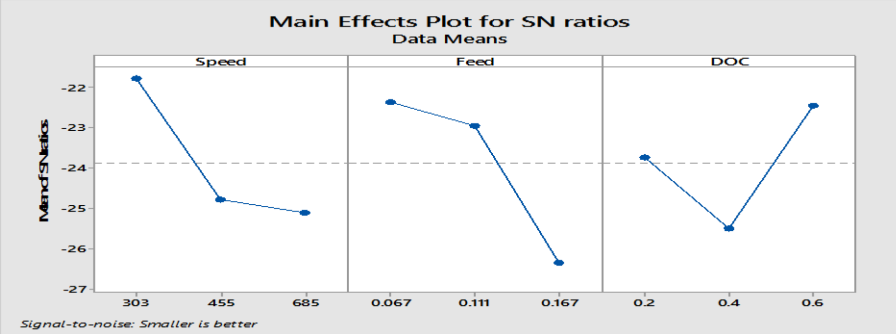

Figure – 3.1, Response Graph for S/N Ratio

B. FOR MEANS –

Table – 3.3, Response Table for Means

Level	SPEED (rpm)	FEED (mm/rev)	DOC (mm)
1	12.60	13.84	16.48
2	18.01	14.27	19.52
3	18.73	21.23	13.34
Delta	6.14	7.39	6.18
Rank	3	1	2

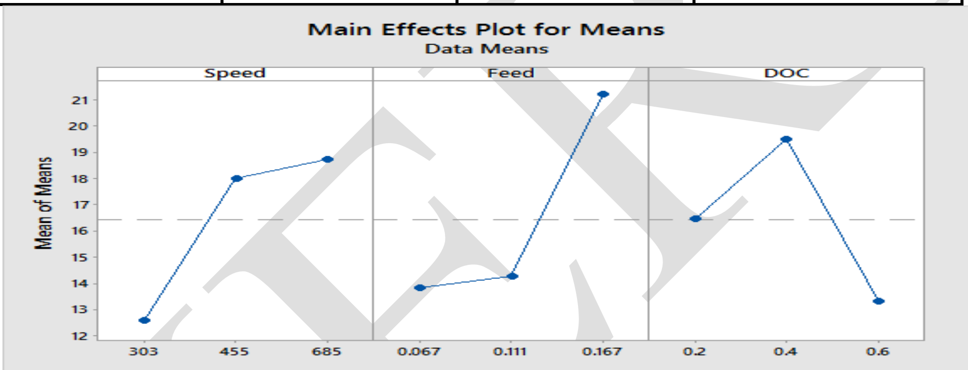

Figure – 3.2, Response Graph for Means

ANANLYSIS BASED ON CUTTING FORCE

I. S/N RATIO CALCULATION

Table – 4.1, S/N Ratio Calculation Based on Cutting Force

Sl No.	SPEED (rpm)	FEED (mm/rev)	DOC (mm)	FORCE	SNRA	MEAN
1	303	0.067	0.2	2	-6.0206	2
2	303	0.111	0.4	4	-12.0412	4
3	303	0.167	0.6	8	-18.0618	8
4	455	0.067	0.4	5	-13.9794	5
5	455	0.111	0.6	8	-18.0618	8
6	455	0.167	0.2	6	-15.5630	6
7	685	0.067	0.6	9	-19.0849	9
8	685	0.111	0.2	3	-9.5424	3
9	685	0.167	0.4	11	-20.8279	11

II. RESPONSE TABLES, GRAPHS & RESULT DISCUSSION

S/N Ratio was calculated based on data of Cutting Force and analysed the result. Two observations response tables and two graphs came as results, where one table and graph for S/N Ratio calculation and another table and graph for Mean calculation.

For S/N Ration calculation, the analysis result came in the form of response table (Table - 4.2), which is calculated by an equation applicable for smaller the better case and the graph shows the graphical output based on the analysis results. In the graph (Figure - 4.1), Speed and Feed and DOC are directly proportional to the Mean of S/N Ratio. From graph, the maximum values of Speed, Feed and DOC was considered, according to the combination of L9 array.

For Mean calculation, the analysis result came in the form of response table (Table - 4.3) and the graph shows the graphical output based on the analysis results. In the graph (Figure - 4.2), Speed and DOC both directly proportional with the Mean of Means and the Feed varies with the Mean of Means. From graph, the minimum values of Speed, Feed and DOC was considered, according to the combination of L9 array.

A. FOR SIGNAL TO NOISE RATIOS –

Smaller is better

Table – 4.2, Response Table for S/N Ratio

Level	SPEED (rpm)	FEED (mm/rev)	DOC (mm)
1	-12.04	-13.03	-10.38
2	-15.87	-13.22	-15.62
3	-16.49	-18.15	-18.40
Delta	4.44	5.12	8.03
Rank	3	2	1

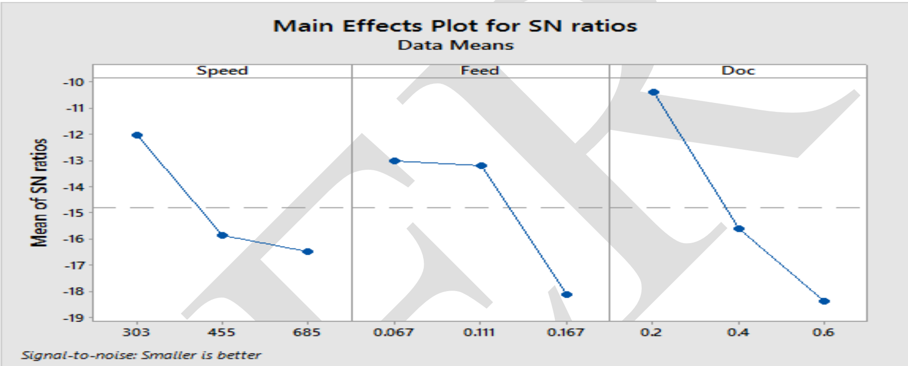

Figure – 4.1, Response Graph for S/N Ratio

B. FOR MEANS –

Table – 4.3, Response Table for Means

Level	SPEED (rpm)	FEED (mm/rev)	DOC (mm)
1	4.667	5.333	3.667
2	6.333	5.000	6.667
3	7.667	8.333	8.333
Delta	3.000	3.333	4.667
Rank	3	2	1

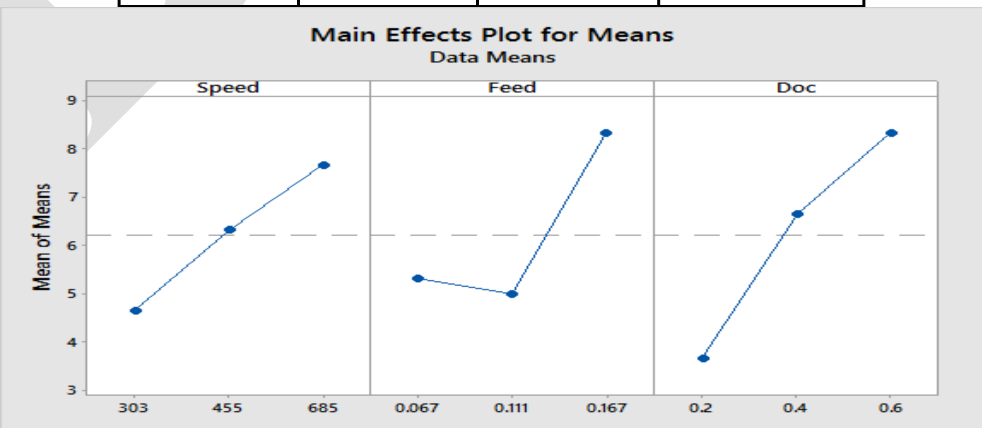

Figure – 4.2, Response Graph for Means

CONCLUSION

The cutting forces are measured by electrical strain gauge dynamometer and the surface roughness are measured by Tally Surf are the best technique available. In the following experimental observation, the surface roughness and the cutting force shows maximum response for the same value of the speed feed and depth of cut.

So the optimal value is given as:

PARAMETERS	INPUT	LEVEL
Speed (rpm)	303	Level - 1
Feed (mm per rev)	0.067	Level - 1
Depth of Cut (mm)	0.2	Level - 1

AUTHOR CONTRIBUTIONS

AC designed the study and discussed the results. SB, SK & SC performed all analysis and wrote the draft of the manuscript. AC supervised and led the whole research. All authors contributed to the final form of the manuscript.

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