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Optimization of Machining Parameters in Turning Operation by Taguchi Method

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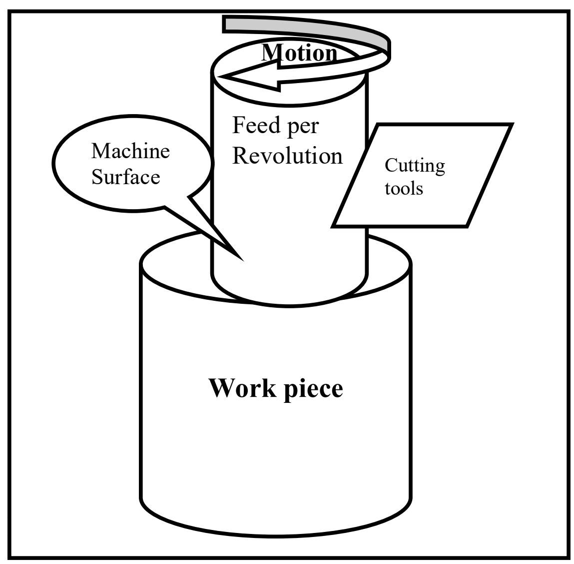
ABSTRACT
In this research paper, optimization and evaluation of machining parameters for turning operation on AISI-1041 mild steel on lathe machining with the help of Taguchi Methods. Taguchi Parameter Design is a powerful and efficient method for optimizing quality and performance output of manufacturing processes, thus a powerful tool for meeting this challenge. The main objective of this investigation is to obtain an optimal setting of process parameters in turning for maximizing the material removal rate of the manufactured component, the MRR has been investigated is the analysis while machining practically used component. As per Taguchi 'DOE', the number of experiments to be conducted in this analysis is calculated, and the turning operations are performed as per the machining conditions shown in the orthogonal array. The data for calculating material removal rate in all the test conditions are observed and recorded. The result of this analysis identifies the optimal values of process parameters for effective and efficient machining.

Keywords: Material removal rate, Surface roughness, Taguchi methods, turning operations.

1. INTRODUCTION

Recent technological advances have lead to increasing number of applications for high strength, low weight, metallic and inter metallic alloys. This has in turn led to an increasing requirement for metal cutting processes. Metal cutting process is one of the important and commonly used manufacturing processes in any metal processing or manufacturing industries [1. Every Manufacturing industry main aims at producing a large number of products within relatively lesser time. it has long been recognized that conditions during cutting, such as feed rate, cutting speed and depth of cu, should be selected to optimize the economics of machining operations as assessed by productivity, total manufacturing cost per components other some other suitable criterion [2]. Increasing the productivity and the quality of the machined parts are the main challenges of metal-based industry; there has been increased interest in monitoring all aspects of the machining process [3, 4]. Turning is the most widely used among all the cutting processes. The increasing importance of turning operations is gaining new dimensions in the present industrial age, in which the growing competition calls for all the efforts to be directed towards the economical manufacture of machined parts and surface finish is one of the most critical quality measures in mechanical products [5]. The Turning is a form of machining or a material removal process which is used to create rotational parts by cutting away unwanted material as shown in Fig. 1.1 The present study is mainly focused on optimization of process parameters of turning operation considering maximization of material removal rate (MRR) as the objective function. Feed rate, spindle speed and cutting speed are considered as process parameters with specified ranges.



2. TAGUCHI METHOD

Taguchi is Conventional methods for experimental design is of complex in nature and difficult to use. Taguchi method is especially suitable for industrial use, but can also be used for scientific Research [6]. In addition to that, these methods also require a large number of experiments when the process parameters increase. In order to minimize the number of

experiments, a powerful tool has been designed for high quality systems by Taguchi [7].
Taguchi approach to design of experiments (DOE) has got high adoptability and hence users can be applied with confined knowledge of statistics, hence gained wide popularity in engineering application.

3. EXPERIMENTAL PROCEDURE

In this experimental setup used for conducting the experiments by using single point cutting tool on **'Automatic High Speed Lathe Machine'** as shown in figure 1.2;

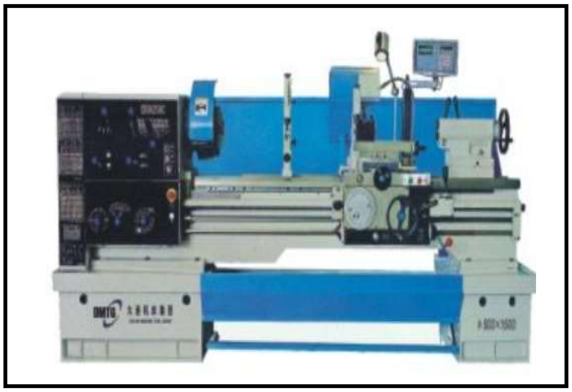


Figure: 1.2 Automatic High Speed Lathe Machine

Taguchi method uses a set of orthogonal arrays to investigate the effect of various process parameters on response characteristic to decide the optimal setting of process parameters [8].

The Taguchi technique helps in data analysis and prediction of optimum results. In order to evaluate optimal parameter settings, Taguchi method uses a statistical measure of performance called signal-to-noise ratio. The S/N ratio takes both the mean and the variability into account. The S/N ratio is the ratio of the mean (Signal) to the standard deviation (Noise). The ratio depends on the quality characteristics of the product/process to be optimized. The standard S/N ratio characteristics can be divided into three categories,

1. ***Nominal-is-Best (NB),***
2. ***Lower-the-better (LB) and***
3. ***Higher-the-Better (HB).***

In this current study, for the maximum material removal rate is taken "Higher the better (HB)/ Lager in better" and S/N ration is determined according to following equation;

Lager in better:

$$\frac{S}{N} = -10 \log \frac{1}{n} \sum \frac{1}{y2} \qquad \text{----------------- (1)}$$

Where,
S/N= Single to Noise Ratio,
n= No. Of measurements,
y= Measured value.

- **The cutting tool materials: -**

The tool is single point tool made of high speed steel. It is grinded after each experiment and the same tool geometry is maintained by bevel protector combination set. The tool used is of British 50th.

- **Work piece Used:-**

AISI-1041 mild steel is used as the work piece material for carrying out the experimentation to optimize the Material Removal Rate. The bars used are of diameter 40mm and length 60mm.

Chemical Composition of AISI-1041

Table: - 1.1 chemical compositions of AISI -1041

S.N	**Metal**	**Range (%)**
1	Magnesium	1.35 – 1.65
2	Carbon	0.42
3	Nickel	1.30-1.70
4	Molybdenum	0.20-0.35
5	Chromium	1.00-1.40
6	Phosphorus	0.017
7	Sulphur	0.008

Mechanical properties of AISI-1041

Table: - 1.2 Mechanical properties of AISI-1041

SN	**Materials AISI-1041**	**Range**	**Unit**
1	Brinell Hardness Number	149	HB
2	Density	7.845	gm/cc
3	Elongation	30.2	%
4	Tensile Strength	518.8	MPa
5	Yield strength	353.44	MPa
6	Poission Ratio	0.27-0.30	------
7	Impact Strength	44-3	J
8	Elastic Modulus	190-210	GPA

9	Tensile Strength	510	MPa
10	Ultimate Tensile Strength	660	MPa

- **Design of Experiment**

The experimental set-up shown in fig.1.2 consists of an Automatic High Speed Lathe Machine turning, an AISI-1041 extruded shaft with diameter of 40mm and length of 60 mm.

The process parameters selected for the present work are tabulated in the table 1.3 According to Taguchi's method, L9 orthogonal array is ideal for conducting the experiments with three control factors (cutting velocity, feed rate and depth of cut) and a variable data type output (energy consumption). An L9 orthogonal array includes 9 combinations and 4 trials (noise factors) in each combination.

Table: - 1.3 The Process Parameter

Factors	Process parameter	Level 1	Level 2	Level 3
1	**Spindle Speed (RPM)**	**340**	**440**	**540**
2	**Feed Rate (mm/rev)**	**0.05**	**0.07**	**0.09**
3	**Depth of Cut (rev)**	**0.4**	**0.8**	**1.2**

- **Data Analyses**

The experiments were carried out based on the process parameters and levels indicated in the table 1.3 and 1.4, and the output characteristic Materials Removal Rate was measured and is tabulated in table1.4 also calculated by S/N ratio using Equation no (1).

Table: - 1.4 Observation of first run experiment

The experimental results are then transformed into signal- to-noise ratio. Taguchi recommends the use of S/N ratio to measure the quality characteristics deviating from the desired values. The material removal rate, in mm^3/sec., has been calculated from following relation:

$$\textbf{MRR} = \frac{\textbf{Initial Weight of Work Piece- Final Weight of Work Piece.}}{\textbf{Time Taken}}$$

Material removal rate is calculated for both set of experiment. Considering one set correct S/N ratio is calculated from MINITAB 16 software.

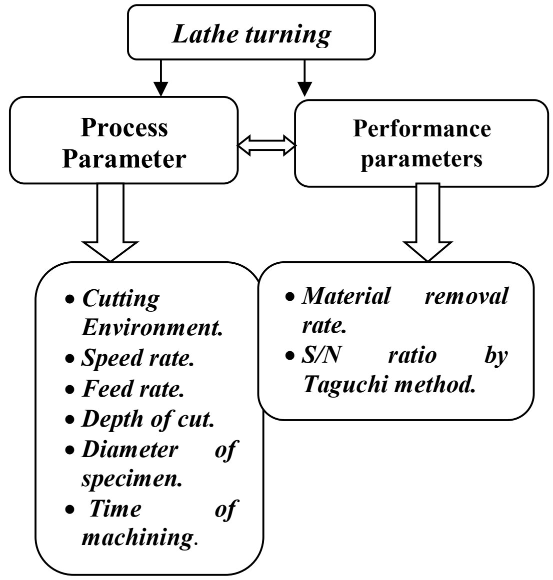


Figure: - 1.3 Lathe turning parameter process versus performance.

Experiment performed:-

Experiments are performed according to the selected design of experiment as shown in table. Machining time is noted by stop watch and measure final weight of all jobs. Material removal rate (MRR) is calculated by using given relation. All the above steps are repeated to perform next set of experiment.

Observation

In the first run nine experiments are performed and material removal rate (MRR) is calculated. When experiments are repeated in second run experiment MRR calculate. The observation table are given below;

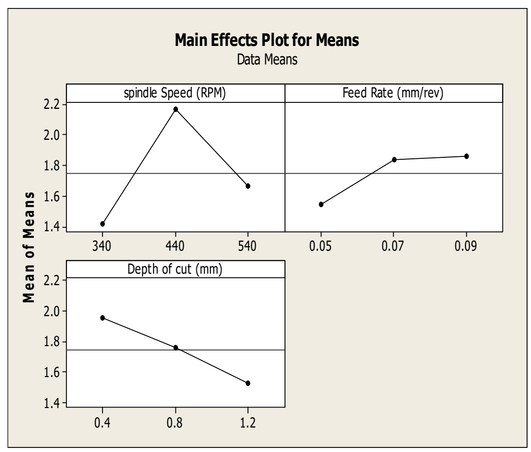
Observation of first Run Experiment				
S. N	**Spindle Speed**	**Feed rate**	**Depth of Cut**	**MRR 1**
	RPM	**mm/rev**	**mm**	**gm/sec**
1	340	0.05	0.4	1.45
2	340	0.07	0.8	1.25
3	340	0.09	1.2	1.58
4	440	0.05	0.8	2.25
5	440	0.07	0.4	2.00
6	440	0.09	1.2	2.26
7	540	0.05	0.4	0.99
8	540	0.07	1.2	2.27
9	540	0.09	0.8	1.69

Observation of Second Run Experiment				
S.N	**Spindle Speed**	**Feed rate**	**Depth of Cut**	**MRR 2**
	RPM	**mm/rev**	**mm**	**gm/sec**
1	340	0.05	0.4	1.42
2	340	0.07	0.8	1.30
3	340	0.09	1.2	1.52
4	440	0.05	0.8	2.20
5	440	0.07	0.4	2.07
6	440	0.09	1.2	2.22
7	540	0.05	0.4	0.99
8	540	0.07	1.2	2.14
9	540	0.09	0.8	1.89

Table: 1.4 Observation of second run experiment

S.N	MRR 1	MRR 2	S/N Ratio	Mean
1	1.45	1.42	3.04577	1.420
2	1.25	1.30	2.10519	1.275
3	1.58	1.52	3.80175	1.550
4	2.25	2.20	6.94496	2.225
5	2.00	2.07	6.16743	2.035
6	2.26	2.22	7.00392	2.240
7	0.99	0.99	-0.08730	0.990
8	2.27	2.14	6.85685	2.205
9	1.69	1.89	5.01638	1.790

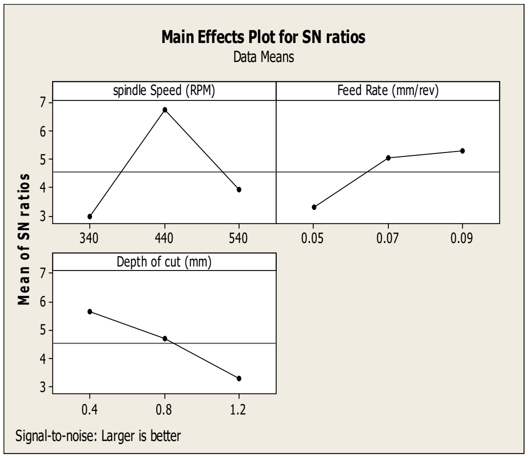
Table: - 1.5 Experimental results and corresponding S/N Ratio



Graph: - 1.1 Main effect plot for means

RESULTS AND DISCUSSION

After finding all the observation as given in Table 1.3 and 1.4, S/N ratio and Means are calculated and various graph for analysis is drawn by using Minitab 16 software. The S/N ratio for MRR is calculated on Minitab 16 Software using Taguchi Method as shown in table no 1.5 also graph plotted with the help of Taguchi method.



Graph: - 1.2 Main effect plot for S/N ratios

CONCLUSION

This research study has presented an application of the parameter design of the Taguchi method in the optimization of turning operations. The following conclusions can be drawn based on the experimental results of this study:

[1] Taguchi's robust orthogonal array design method is suitable to analyze the MRR (metal cutting) problem as described in this paper.

[2] The experimental results demonstrate that the insert spindle speed and feed rate are the main parameters among the three controllable factors (spindle speed, feed rate and depth of cut) that influence the material removal rate in turning AISI-1041 mild steel.

[3] The Material removal rate is mainly affected by cutting speed and feed rate. With the increase in cutting speed the material removal rate is increases & as the feed rate increases the material removal rate is increases.

[4] Material Removal rate can be improved simultaneously through this approach instead of using engineering judgement. The confirmation experiments were conducted to verify the optimal cutting parameters.

[5] Deviations between actual and predicted S/N ratio of material removal rate are small each parameter.

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