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Optimization of Machining Parameters for Mild Steel in Dry Turning Using Taguchi Method

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ABSTRACT: *In present days every manufacturing industry thrives hard to produce quality products at an economical price while fulfilling the requirements of both manufacturer and the customer who happens to the end user of the product. Machining of sophisticated parts has posed a greater challenge to manufacturer. Optimization techniques like Taguchi method has been introduced and widely applied in industries in order to achieve the desiredgoals. In this analysis, an attempt is made to study the effects of machining parameters like speed, feed and depth of cut in a turning operation of mild steel by employing one of the widely used Optimization techniques which is Taguchi Method. The main input machining parameters namely Speed, Feed and Depth of cut are taken Page 7 into consideration, while the output parameter Material Removal Rate (MRR) is considered as the response variable. Taguchi method is applied and signal-to-noise ratio is calculated using L9 Orthogonal Array (OA) with the help of Minitab software. Based on the graphs from the Minitab software optimum levels of machining parameters were obtained and maximization of material removal rate (MRR) is found out and the same is checked experimentally in a machining workshop*

Keywords: *Optimization technique, Taguchi Method, Turning Operation, Material Removal Rate, Minitab* software.

I. Introduction

In the present scenario, quality plays a vital role in today's manufacturing world due to complex working environment and conditions. Every new material which comes into existence we need efficient and economical machining. Machining is the most common and versatile manufacturing process employed by engineering or manufacturing industries that creates component of desired shape, size and finish by removing the excessive or unwanted material from a larger piece of a work piece. The process of machining is affected by relative motion between the tool and the work piece. The literature survey has revealed that several researchers and scientists have attempted to calculate the optimum cutting conditions in a turning operation on EN 24 stainless steel, AISI 8660 hardened alloy steel, AISI 316 stainless steel and other various alloys. In this study, an attempt is made to demonstrate the application of Taguchi's method to study the effects of machining parameters on a low carbon mild steel work piece in a turning operation on a lathe machine.

II. Approach to Product/Process Development

In this turning operation, Spindle Speed, Feed Rate, Depth of Cut are considered as input parameters. These are the main factors which primarily have a direct effect on the work piece. All these factors are adjusted by the operator on the machine.

Cutting Speed

The speed of work piece surface relative to the edge of the cutting tool during a cut measured inm meter per minute.

It is given by the formula: $\mathbf{V_C = \pi DN/1000}$

Spindle Speed

The rotational speed of the spindle and the work piece in revolutions per minute (RPM). Thespindle speedis equal to the cutting speed divided by the circumference of the work piece where the cut is being made in order to maintain a constant cutting speed; the spindle must vary based on the diameter of the cut. If the spindle speed is held constant, then cutting speedwill vary. It is also called as surface speed or cutting speed.

Feed Rate

Feed rate (or simply feed) is the relative velocity at which the cutter is advanced along the work piece. The speed of the cutting tool's movement relative to the work piece as the tool makes a cut. The feed rate is measured in mm per revolution.

It is given by the formula: $\mathbf{Fm = f \times N}$

Where

Fm is feed in mm/min

f is feed in mm/rev

N is speed of spindle in r.p.m

Depth of Cut

The depth of the tool along the radius of the work piece as it makes a cut, asin a turning or boring. A large depthof cut will require a low feed rate, or else it will result in a high load on the tool and reduce the tool life.

It is given by the formula: **d = D1-D2**

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III. Steps Involved in Taguchi Method

The use of Taguchi's parameter design involves the following steps.

a. Identify the main function and its side effects.

b. Identify the noise factors, testing condition and quality characteristics.

c. Identify the objective function to be optimized.

d. Identify the control factors and their levels.

e. Select a suitable Orthogonal Array(OA) and construct the Matrix

f. Conduct the Matrix experiment.

g. Examine the data; predict the optimum control factor levels and its performance.

h. Conduct the verification experiment.

IV. Approach to the Experimental Design

In accordance with the steps that are involved in Taguchi's Method, a series of experiments are to be conducted. Here, turning operation on low carbon mild steel work piece using a lathe has been carried out as a case study. The procedure is given below.

Identification of Main Function and its side effects

a) Main function: Facing Operation on Low Carbon Mild Steel work piece using lathe machine

b) Side effects: Maximization of Material Removal Rate.

Identification of Control & noise factors

The below table lists the various control and noise factors that influence the turning operationon lathe machine:Table 4.2: Identification of Control & noise factors

Control factors	Noise Factors
Cutting speed	Vibration
Depth of cut	Raw material variation
Feed rate	Machine Condition
Nose radius	Temperature

After While carrying out the experiment the factors that significantly affect the performance will have tobe ascertained and onlythose factors must be taken into consideration in constructingthe matrix of experimentation. The remaining factors are considered as Noise factors.

Identifying of Testing Conditions and Quality Characteristics

Material used: Low Carbon Mild Steel

Machine Tool Used: Turning operation on a Lathe MachineCutting tool: Tungsten: Carbide Tipped tool

Identify of Objective Function

Objective Function: Smaller-the-Better

S/N Ratio for this function: $\eta = -10\log_{10}\left(\frac{1}{n}\sum_{i=1}^{n} y^2{}_i\right)$ Where, n= Sample Size, and y= MRR in that trial.

Identifying the Control Factors and their levels

The various control factors and their levels are shown in below table:

Table 4.2 Selected Factors and their Levels.

Control factors	Levels		
	1	**2**	**3**
Speed (v, RPM)	120	700	1100
Feed rate(f, mm/min)	0.096	0.382	0.764
Depth of Cut (t, mm)	0.8	1.6	2.4

Selection of Orthogonal Array

To select an appropriate orthogonal array for conducting the experiments, the degrees of freedom are tobe computed. The same is given below:

Degrees of Freedom: 1 for Mean Value, and

8= (2x4), two each for the remaining factorsTotal Degrees of Freedom: 9

The most suitable orthogonal array for experimentation is L9 array as shown in Table Therefore, a total nine experiments are to be carried out. Taguchi Orthogonal array is designed with three levels of turning parameters with the help of software Minitab

Table 4.3 Taguchi L9 Orthogonal Array (OA)

Experiment No.	**Control Factors**		
	Cutting Speed(v, RPM)	**Feed rate (f, mm/min)**	**Depth of Cut (t, mm)**
1	1	1	3
2	1	2	2
3	1	3	1
4	2	1	2
5	2	2	1
6	2	3	3
7	3	1	1
8	3	2	3
9	3	3	2

Conducting The Matrix Experiment

In accordance In accordance with the above OA, experiments were conducted with their factors and their levels as mentioned in above table. The MRR was measured using the surface roughness tester.

Table 4.4 Orthogonal Array (OA) With Machining parameters

ExperimentNo.	**Control Factors**		
	(v, RMP)	**(f, mm/rev)**	**(t, mm)**
1	120	0.096	0.8
2	700	0.096	1.6
3	1100	0.096	2.4
4	120	0.382	1.6
5	700	0.382	2.4
6	1100	0.382	0.8
7	120	0.764	2.4
8	700	0.764	0.8
9	1100	0.764	1.6

Measurement of MRR:

After carrying out the experiments according to the selected parameters as shown in above table, the time taken for each run is noted by using a stopwatch and MRR is calculated by the formula

MRR = (Initial weight – Final Weight)/time.

Observation

The after carrying out the experiment all the readings of MRR and time taken along with the processparameters are tabulated below:-

Table 4.5 Orthogonal Array (OA) With Machining parameters and MRR

ExperimentNo	**Spindle Speed (v, RPM)**	**Feed rate (f, mm/rev)**	**Depth of Cut (t, mm)**	**MRR(m3 /sec)**
1	120	0.096	0.8	11.46
2	700	0.096	1.6	131.37
3	1100	0.096	2.4	309.19
4	120	0.382	1.6	85.66
5	700	0.382	2.4	732.53
6	1100	0.382	0.8	442.43
7	120	0.764	2.4	238.48
8	700	0.764	0.8	531.82
9	1100	0.764	1.6	1626.36

Examination of Data

After finding the MRR, With the help of Minitab15 software and applying Taguchi Method,the signal-to-noise ratio and means are calculated and graphs are plotted. The steps used areas follows:

Experimental Results & Corresponding S/N Ratio:

Higher Material Removal Rate is considered as the response variable in the analysis. The objective of this study (higher MRR) is larger-the-better type of control function, was used in calculating the S/N ratio. The S/N ratioof all the experiments was calculated using Minitab15 software and tabulated as shown below:

Table 4.6 Machining parameters and its corresponding response variable along with S/N Ration

ExperimentNo	Cutting Speed (v, RPM)	Feed rate (f, mm/rev)	Depth of Cut (t, mm)	MRR (m^3/sec)	S/N Ratio (dB)
01	120	0.096	0.8	11.46	21.18
02	700	0.096	1.6	131.37	42.36
03	1100	0.096	2.4	309.19	49.80
04	120	0.382	1.6	85.66	38.65
05	700	0.382	2.4	732.53	57.29
06	1100	0.382	0.8	442.43	52.91
07	120	0.764	2.4	238.48	47.54
08	700	0.764	0.8	531.82	54.51
09	1100	0.764	1.6	1626.36	64.22

Discussion

An analysis of the influence of each factor (Cutting speed, Depth of Cut, Feed Rate) on theMRR was performed with means and S/N ratio response table using Minitab15 software.

In this experiment "**larger is the best"** for Signal-to-Noise is taken into consideration.The responsetable for Means is shown below:

Table4.7 Response tables for means

Level	Spindle Speed	Feed	Depth of Cut
1	111.8	150.7	328.6
2	465.2	420.2	614.4
3	792.6	798.8	426.7
Delta	680.8	648.2	285.9
Rank	1	2	3

The response table for S/N Ratio is shown below:

Table 4.8 Response table for S/N ratio

Level	Spindle Speed	Feed	Depth of Cut
1	35.8	37.79	42.87
2	51.39	49.62	48.42
3	55.65	55.43	51.55
Delta	19.85	17.64	8.68
Rank	1	2	3

According to above tables both the means and S/N ratio tables state that SpindleSpeed playsa vital role in higher MRR followed by feed and depth of cut.

Graphs VIA Minitab software:

Two graphs namely Main Effects Plot for Means and Main Effects Plot for S/N ratio areplotted with the helpof Minitab15 software.

FIG 1 Main Effects Plot for Means

Main Effects Plot for Means

Figure 1 depicts the main effects plot for means. When closely observed when the processparameters like spindle speed is increased from 120 rpm to 500 rpm and to 800 rpm, the material removal rate is increased, the MRR is also increased when the feed is increased from 0.096 to 0.382 mm/rev and to 0.764 mm/rev. Interestingly when the the depth of cut is increased to 0.8 to 1.6 mm the MRR has increased however the MRR has decreased when the depth of cut is increased to 2.4mm.

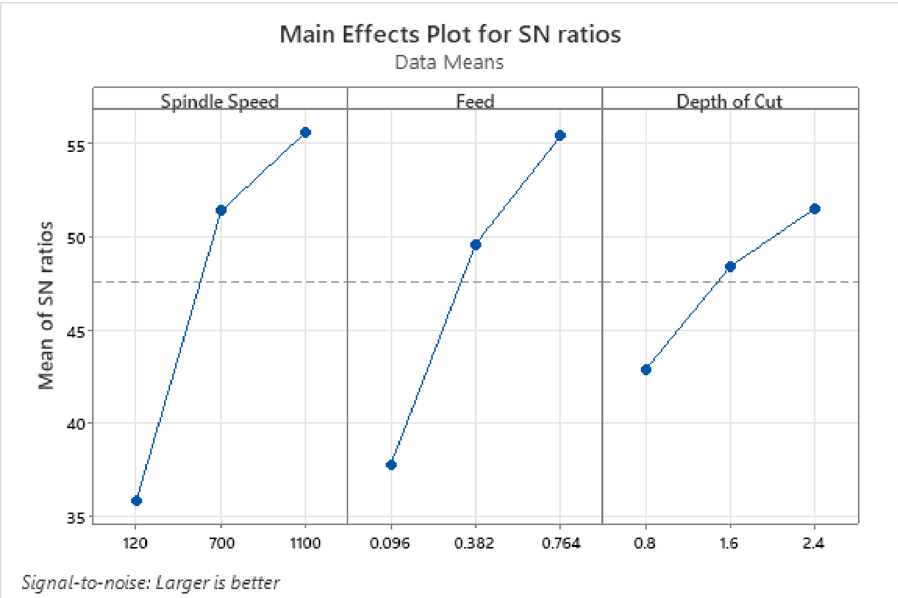

FIG 2 Main Effects Plot for S/N Ratio

Main Effects Plot for S/N Ratio

Figure 2 depicts the main effects plot for S/N ratio. We can clearly assess from the above graph that the Material Removal Rate is increased when spindle speed, feed and depth of cutare increased.

Effects of Turning Parameters on Material Removal Rate for signal-to-noise ratio:

Cutting Speed:

The effect of spindle speed on the MRR is shown in above figure. Its effect is increasing withincrease in cutting speed up to 1100 rpm .So the optimum cutting speed is level 3 i.e. 1100 rpm.

Feed Rate:

The effect of feed is increasing with increase in feed rate from0.096 to 0.764 mm/rev. So theoptimum feed rate is level 3 i.e. 0.764 mm/rev.

Depth of Cut:

The effect of depth of cut is increasing with increase in depth of cut from 0.8 to 2.4 mm. So the optimum depth of cut is level 3 i.e. 2.4 mm.

Optimum Results:

The factor levels corresponding to the highest S/N ratio were chosen to optimize the condition. From these graphsit is clear that the optimum values of the factors and their levelsare as given in below table:

Table 4.9 Optimum Values of factors

Parameter	Optimum Value
Spindle Speed (rpm)	1100
Feed Rate (mm/rev)	0.764
Depth of Cut (mm)	2.4

V. CONCLUSION

This study illustrates when an optimization technique like Taguchi method is applied in a turning operation. Thefollowing conclusions can be drawn based on the above experimentalresults of this study:

- MRR is influenced by the parameters like Spindle speed, feed and depth of cut. All the parameters aredirectly proportional to Material Removal Rate
- The optimal process parameters can be ascertained for the maximum Material Removal Rate withlesser number of experiments.
- It is also understood that the Taguchi method provides a simple, systematic, and efficient methodology for optimizing the process parameters.

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