# Optimization of Cutting Parameters for EN 24 Grade Steel using Taguchi Method in Turning

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*Abstract*— Turning operation will carry out on EN24 grade steel (46 HRC) with TNMG Insertion CNC Machine. Therefore three cutting parameters namely cutting speed, feed and depth of cut need to be determined in turning operations. The settings of machining parameter will determine by using Taguchi`s experimental design method. Orthogonal array of Taguchi, the signal to noise (S/N) ratio, the analysis of variance (ANOVA) will apply to find the optimal levels and to analyze the effect of cutting parameter. The result obtained by this method will be useful to other researchers for similar type of study and may be eye opening for further research on tool vibration, cutting forces etc.

***Key words:*** Turning, Taguchi Method, Orthogonal Array, ANOVA, S/N Ratio, MRR

## I. Introduction

The challenge of modern machining industries is mainly focused on the achievement of high quality, in terms of work piece dimensional accuracy, surface finish, high production rate, less wear on the cutting tools, economy of machining in terms of cost saving and increase in the performance of product with reduced environmental impact[6]. In machining, the speed and the motion of cutting tool is specified through several parameters. These parameters are selected for each operation based upon the work piece material, tool material, tool size and more[10]. The Taguchi method is a well-known technique that provides a systematic and efficient methodology for process optimization and this is powerful tool for the design of high quality system [10].

In the present investigation, a single characteristics optimization model based on Taguchi method employed to determine the best combination of machining parameter such as cutting speed, feed rate and depth of cut to attain maximum material removal rate (MRR)[5].

## II. Material Removal Rate (MRR)

Material removal rate (MRR) in turning is the material that is removed per unit time in mm/sec. For each revolution of the work piece, a ring shaped layer of material is removed. [10]

MRR = [$\pi$x (Davg) x d x f x N]/ 60 $mm^3$/sec

Where, Davg = Average Diameter in mm

N = cutting speed in RPM

d = depth of cut in mm

f = feed in mm/rev

## III. Taguchi Method and Orthogonal Array

The philosophy of Taguchi is widely used. He suggested that engineering optimization of a process or product should be carried out in a three step approach. i.e., system design, parameter design and tolerance design. In system design, the engineer applies scientific and engineering knowledge to produce a basic functional prototype design, this design including the product design stage, the selection of materials, components, tentative product parameter values, etc., are involved [5].

The traditional experimental designs are too much complex and time consuming. To overcome limitations of traditional method the Taguchi method is used. Advantages of implementation of Taguchi method are: To find out significant factors in a shorter time period, to decrease the cost, decrease the experimental time. The Taguchi method is mostly used to design the best process parameter to minimize the variation [10].

Taguchi has introduced an important tool named orthogonal array to do experiment with various combination of parameters and with reduced number of experiments. We had chosen three factors such as cutting speed, feed and depth of cut at three different levels. With that three levels and three factors we used L9 orthogonal array.

## IV. Experiment

The experiment was conducted using the work piece material namely EN24 grade steel rod with TNMG insert tool.

The test was carried for a length of 125mm and diameter of 23.8mm in a SPEED GX-100 CNC.

The cutting parameters are shown in table 1. Three levels of cutting speed, three levels of feed and three levels of depth of cut were used and are shown in table 1.

The different alloying elements present in a work piece are shown in the table 2.

| Cutting parameter | Level 1 | Level 2 | Level 3 |
|---|---|---|---|
| Cutting speed (in rpm) | 1500 | 1800 | 2000 |
| Feed rate (mm/rev) | 0.15 | 0.2 | 0.25 |
| Depth of cut (mm) | 0.5 | 0.75 | 1 |

Table 1:

| Material | C % | Cr % | Ni % | M % | Si % | Mn % | S % | P % |
|---|---|---|---|---|---|---|---|---|
| **EN24 steel** | 0.36 - 0.44 | 1-1.4 | 1.3-1.7 | 0.2-0.35 | 0.1 - 0.35 | 0.45-0.7 | 0.04 | 0.035 |

Table 2: Composition of EN24 grade steel

## V. Result

Observations from experiment:

Diameter of rod (before experiment) = 23.8mm

| Exp. no. | Cutting speed (rpm) | Feed rate (mm/rev) | Depth of cut (mm) | Diameter (mm) | Davg (mm) |
|---|---|---|---|---|---|
| **1** | 1500 | 0.15 | 0.5 | 22.83 | 23.3 |

| | | | | | |
|---|---|---|---|---|---|
| **2** | 1500 | 0.2 | 0.75 | 22.33 | 23.06 |
| **3** | 1500 | 0.25 | 1 | 21.85 | 22.82 |
| **4** | 1800 | 0.15 | 0.75 | 22.33 | 23.06 |
| **5** | 1800 | 0.2 | 1 | 21.83 | 22.82 |
| **6** | 1800 | 0.25 | 0.5 | 22.86 | 23.33 |
| **7** | 2000 | 0.15 | 1 | 21.82 | 22.81 |
| **8** | 2000 | 0.2 | 0.5 | 22.82 | 23.31 |
| **9** | 2000 | 0.25 | 0.75 | 22.6 | 23.2 |

Table 3: Observation Table

### *A. After Calculation:*

*1) Formula for calculation of MRR:*

MRR =[$\pi$x (Davg) x (DOC) x (Feed rate) x (Cutting speed)]/60

*2) Results from Minitab 17 software for S/N ratio and Graphs:*

| **Exp.no.** | **Cutting speed (rpm)** | **Feed rate (mm/ rev)** | **Depth of cut (mm)** | **MRR ($mm^3$/sec)** | **SNRA1** |
|---|---|---|---|---|---|
| **1** | 1500 | 0.15 | 0.5 | 137.24 | 42.7496 |
| **2** | 1500 | 0.2 | 0.75 | 271.66 | 48.6805 |
| **3** | 1500 | 0.25 | 1 | 448.06 | 53.0267 |
| **4** | 1800 | 0.15 | 0.75 | 244.5 | 47.7656 |
| **5** | 1800 | 0.2 | 1 | 430.14 | 52.6722 |
| **6** | 1800 | 0.25 | 0.5 | 274.85 | 48.7819 |
| **7** | 2000 | 0.15 | 1 | 358.29 | 51.0847 |
| **8** | 2000 | 0.2 | 0.5 | 244.10 | 47.7514 |
| **9** | 2000 | 0.25 | 0.75 | 455.53 | 53.1703 |

Table 4: Results from Minitab 17 software for S/N ratio and Graphs

### *B. Higher the Better Signal to Noise Ratio is calculated in Column Snra1*

And Respective Graphs are Plotted for Visual Inspection.

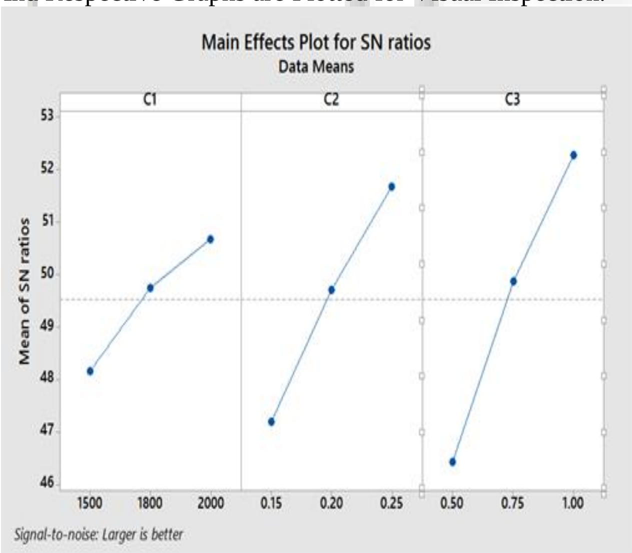


Fig. 1: Graphs are plotted for Visual Inspection

### *C. ANOVA table is also generated to show the influence of each factor using Minitab 17:*

| Source | DF | Adj SS | Adj MS | F value | P value |
|---|---|---|---|---|---|
| Speed | 2 | 6745 | 3372 | 2.71 | 0.27 |
| Feed rate | 2 | 32073 | 16037 | 12.88 | 0.072 |
| Depth of cut | 2 | 56267 | 28134 | 22.6 | 0.042 |
| Residual error | 2 | 2489 | 1245 | | |
| Total | 8 | 97575 | | | |

Table 5: ANOVA table is also generated to show the influence of each factor using Minitab 17

## VI. Conclusion

The Taguchi experimental design was used to obtain optimum cutting parameter on turning. L9 orthogonal array was selected for three different level of cutting speed, feed and depth of cut. Nine experiments were conducted instead of 27 experiments. The results obtained from this experiment were:

By using S/N ratio equation "Higher the better", the maximum value was obtained by the maximum S/N ratio. Optimum cutting conditions which corresponds to maximum 53.1703 S/N value of the MRR for turning was found to be 2000 rpm for cutting speed, 0.25 mm/rev for feed rate, 0.75 mm for depth of cut.

From the ANOVA table and the P value, the depth of cut is the significant factor which contributes to the material removal rate (MRR) with 0.042 P value.

Feed is also a significant factor with p value of 0.072 and cutting speed is less significant.

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