

# Experimental Investigation on Surface Roughness in Finish Turning of EN 8 Steel

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**Abstract:** *Good surface quality is the requirement of customers. In the present work it was seen that the desired surface roughness were not obtained consistently in turning of EN 8 steel application (shaft). These higher values of surface roughness results in rework and increases cost hence the main objective is optimization of surface roughness. The surface quality is influenced by cutting speed, feed rate and depth of cut and many other parameters. In the present study attempt has been made to investigate the effect of cutting parameters (cutting speed, feed rate, depth of cut) on surface roughness in the finish turning of EN 8 steel. The CNMG 120412 cutting tool insert was used for experimental work. The experiments have been conducted using Taguchi L9 orthogonal array in a SPEED LX 200 MAJOR CNC lathe machine. Turning process carried out on the EN 8 steel. The optimum cutting condition was determined surface roughness were evaluated by the analysis of variance (ANOVA).*

**Keywords:** Turning, Surface roughness, ANOVA, Taguchi Method, S/N ratio

## 1. Introduction

Metal cutting processes are industrial processes in which metal parts are shaped or removal of unwanted material is done. Turning is one such machining process which is most commonly used in industry because of its ability to have faster material removal at the same time it produces reasonably good surface finish quality. It is one of the most important and widely used manufacturing processes in engineering industries. In the study of metal cutting, the output quality is rather important. A significant improvement in output quality may be obtained by proper tool and work piece combination followed by optimizing the cutting parameters. Tool insert not only improves output quality, but also ensures low cost manufacturing. Tool insert includes tool insert geometry such as nose radius, approach angle, rake angle, angle of inclination, clearance angle etc. Cutting parameters include feed rate, cutting speed, depth of cut, cutting fluids and so on. The three input parameters such as cutting speed, feed rate and depth of cut are selected in this research work. Surface roughness selected as output parameter.

In machining of parts, surface quality is one of the most specific customer requirements where major indication of surface quality on machined parts is surface roughness value [1]. EN8 or 080M40 is unalloyed medium carbon steel which has medium strength and good tensile strength; it is suitable for manufacture of shafts, studs, keys, general purpose axles etc [7]. Jawaid et.al [2] shows that surface finish is an important parameter in manufacturing engineering. It is a characteristic that can influence the performance of mechanical parts and production costs. They have observed low surface roughness with increase of cutting speed. Patel et al. [3] have considered a novel approach for optimum cutting tool insert selection strategy. In this approach, two well-known Multiple Attribute Decision Making (MADM) methods such as Simple Additive Weighting (SAW) and Weighted Product Method (WPM) use for a case study of tool insert selection for better

surface finish in CNC (Computer Numerical Control) turning operation. In these methods their relative performance are compared with respect to ranking of alternative and from ranking they have selected best tool insert for better surface quality during turning operation on alloy steel using CNC turning centre. Bhattacharya et al. [4] have investigated the effect of cutting parameters on surface finish and power consumption during high speed machining of AISI 1045 steel using Taguchi design and ANOVA. The result showed a significant effect of cutting speed on surface roughness and power consumption, while the other parameters have not substantially affected the response. Thangarasu et al. [5] studied relationship with the basic parameters to the responses namely Surface roughness (Ra) and Material Removal Rate (MRR). Depth of cut for better surface finish and material removal rate. The Ra and MRR is resultant of various controllable process parameters are Spindle speed, Feed rate and Depth of Cut. Depth of cut was found as the most critical factor for attaining the desired MRR while reducing the value of surface roughness. Kabra et al. [6] studied on three machining parameters as process parameters: Cutting Speed, Feed rate and Depth of cut. The experimentation plan is designed using DOE and Minitab-16 statistical software is used. Optimal values of process parameters for desired performance characteristics are obtained by design of experiment. Prediction models are developed with the help of regression analysis method using Minitab-16 software and finally the optimal and predicted results are also verified with the help of confirmation experiments. Ilhan Asilturk and Harun Akkus [8] obtained the effect of cutting parameters on surface roughness in hard turning using the Taguchi method. In this study, dry turning test carried out on hardened AISI 4140 (51 HRC) with coated carbide cutting tools. The statistical methods of signal-to-noise (S/N) ratio and analysis of variance (ANOVA) are applied to obtain effect of cutting parameters on surface roughness. Kumar et al. [13] obtained the effect of spindle speed and feed rate on surface roughness of Carbon Alloy Steel in CNC turning. In this study, five different carbon steel used for turning are SAE

8620, EN8, EN19, EN24 and EN47. As a result, it was concluded that the surface roughness increased with increased feed rate and it higher at lower speeds and vice versa.

The objective of this study is obtain optimal turning conditions (cutting speed, feed rate and depth of cut) for minimizing the Ra when turning EN 8 steel material with CVD coated carbide insert. The cutting insert is selected by MADM (Multiple Attribute Decision Making) method. Taguchi's L9 Orthogonal Array was used in the design of experiment. Furthermore, analysis of variance (ANOVA) is performed to see which process parameters are statistically significant.

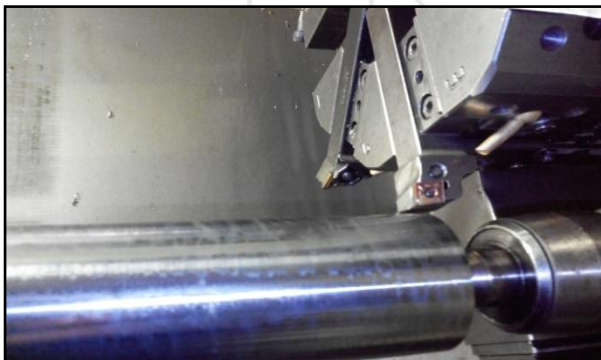
## 2. Experimental Details

### 2.1 Material

The sample was EN 8 steel in the form of round bar with 110 mm diameter and 1000 mm cutting length. This steel is especially recommended for the manufacture of shafts, studs, keys, general purpose axles, camshafts etc. In the study it is used for camshaft application. The hardness range is 28-32 HRC.

**Table 1:** Chemical composition of EN 8 steel

C%	Si%	Mn%	S%	P%
0.35/0.45	0.05/0.35	0.60/0.10	0.06 max	0.06 max



**Figure 1:** Experimental setup

### 2.2 Cutting inserts

In this experimental study CVD (TiN) coated carbide inserts used as the cutting tool material. The TaeguTec inserts with the ISO designation of CNMG 120412FC-TT5100 (80° Rhombic insert) was used. For CNMG insert PCLNL 2525 M12 tool holder was used. The cutting tool insert was selected by MADM (Multiple Attribute Decision Making) method.



**Figure 2:** Cutting tool insert with tool holder

### 2.3 Cutting condition and surface roughness

**Measurements** The experiments carried out under wet environment using SPEED LX 200 MAJOR CNC lathe which have maximum spindle speed of 3500 rpm and a maximum spindle power of 15 kw. The coolant used is water soluble oil (Metcut brand). After the experiments, Average surface (Ra) value which is one of the most important machinability criteria was measured by using Mitutoyo's SJ-301 SurfTest surface roughness tester within sampling length 2.5 mm.



**Figure 3:** Surface roughness tester

In this study, three factors were studied and their low-middle-high levels are given in Table 1.

**Table 2:** Cutting parameters

Factor	Cutting parameters	Level 1	Level 2	Level 3
Vc	Cutting speed (m/min)	200	225	250
F	Feed (mm/rev)	0.2	0.23	0.25
DOC	Depth of cut (mm)	0.5	1	1.5

## 3. Design of Experiments

Experiments have been carried out using Taguchi's L9 Orthogonal Array (OA) experimental design which consists of 9 combinations of cutting speed, longitudinal feed rate and depth of cut. It considers three process parameters (without interaction) to be varied in three discrete levels. The Signal to Noise (S/N) ratio is used to measure the quality characteristics and is also used to measure the significant machining parameters through the analysis of variance (ANOVA). The experimental design has been shown in Table 4 (all factors are in coded form).

**Table 3:** Process variables and their limits

Process variables			
Values in coded form	Cutting speed (Vc) (mm/min)	Feed (F) (mm/rev)	Depth of cut (DOC) (mm)
-1	200	0.2	0.5
0	225	0.23	1
+1	250	0.25	1.5

**Table 4:** Taguchi's L9 Orthogonal Array  
 L9 (3\*\*3)  
 Factors: 3  
 Runs: 9

Experimental No.	Vc	F	DOC
1	-1	-1	-1
2	-1	0	0
3	-1	+1	+1
4	0	-1	0
5	0	0	+1
6	0	+1	-1
7	+1	-1	+1
8	+1	0	-1
9	+1	+1	0

The values of cutting speed, feed and depth of cut are taken from tool manufacturing catalogue. The codes are given to the each level of cutting parameters so this is helpful to make 9 trials of experimentation. The process variables with their units (and notations) are listed in Table 3.

**Table 5:** The results of experiments and S/N ratios values for insert CNMG 120412 FC

Exp.No.	Vc	F	DOC	Ra	S/N of Ra
1	200	0.2	0.5	1.34	-2.5421
2	200	0.23	1	1.56	-3.86249
3	200	0.25	1.5	1.94	-5.75603
4	225	0.2	1	1.41	-2.98438
5	225	0.23	1.5	1.63	-4.24375
6	225	0.25	0.5	2.05	-6.23508
7	250	0.2	1.5	1.36	-2.67078
8	250	0.23	0.5	1.84	-5.29636
9	250	0.25	1	1.93	-5.71115

#### 4. Results and Discussions

The most essential criterion in the Taguchi technique for analyzing experimental data is signal-to-noise ratio. In this experimental study, the S/N ratio should have a maximum value to obtain optimum cutting conditions, according to the Taguchi method. Thus, the optimum cutting condition was found as -2.5421 S/N ratio for Ra value in L9 orthogonal array in Table 5. The optimum cutting conditions, which were the cutting speed of 200 m/min, the feed rate of 0.2 mm/rev and the depth of cut of 0.5 mm (1 1 1 orthogonal array) were obtained for the best Ra values. Level values of the factors obtained for Ra value according to the Taguchi design is given in Table 6. Figure 4 shows the graphic of the level values given in Table 6. Therefore, interpretations may be made according to the level values of Vc, F, and DOC factors given in Table 6 and Figure 4 in determining optimum cutting conditions of experiments to be conducted under the same conditions. The average S/N ratio for every level of experiment is calculated based on the recorded value as shown in Table 6.

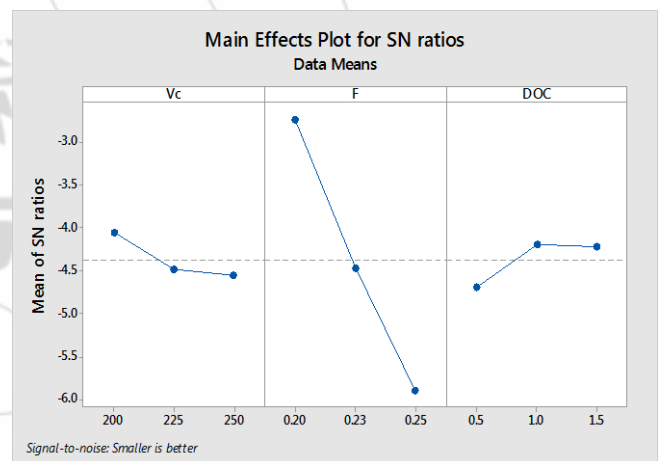
**Table 6:** S/N response table for Ra factor

Level	Vc	F	DOC
1	-4.05	-2.732	-4.691
2	-4.49	-4.468	-4.186
3	-4.56	-5.901	-4.224
Delta	0.506	3.168	0.505
Rank	2	1	3

The different values of S/N ratio between maximum and minimum are (main effect) also shown in Table 6. The feed is one factors that have the highest difference between values such as 3.168.

The other two factors such as cutting speed and depth of cut has very low difference values compared to feed. Based on the Taguchi prediction that the larger difference between values of S/N ratio will have a more significant effect on surface roughness (Ra). Thus, it can be concluded that increasing the feed will increase the Ra significantly.

MINITAB is Statistical Analysis software that allows to easily conducting analysis of data. The MINITAB 17 program studies the experimental data and then provides the calculated results of signal-to-noise ratio. In this experimental work, the software has given the signal-to-noise ratio for surface roughness. The effect of different process parameters on surface roughness are calculated and plotted as the process parameters changes from one level to another. The use of both ANOVA and S/N ratio statistical method makes it easy to analyze the results and hence, make it fast to reach on the conclusion. From Figure 4, it can be seen that surface roughness is least affected by cutting speed and depth o cut. From figure 4, it can be seen that with increase of feed rate surface roughness value would increase.



**Figure 4:** Effect of parameters on process performance (Ra)

**Table 7:** Analysis of Variance of SN ratios for Surface roughness Ra

Source	DF	Adj SS	Adj MS	F-Value	P-Value	% contribution
Vc	2	0.01647	0.008233	1.08	0.481	2.745
F	2	0.54607	0.273033	35.77	0.027	91.012
DOC	2	0.0222	0.0111	1.45	0.407	3.700
Error	2	0.01527	0.007633			2.545
Total	8	0.6				100.002

In ANOVA if the P value of factor is less than 0.05 then that factor is significant and if P value is more than 0.05 then that factor is insignificant. Table 7 shows the analysis of variance for surface roughness Ra value. It is clear from the table 8 that the feed rate is the most significant factor for surface roughness. Effect of cutting speed and depth of cut is insignificant in the present study as compared with other cutting parameters for surface roughness Ra value.



## 5. Conclusion

From the analysis of the results in the turning process using the signal-to-noise (S/N) ratio approach, analysis of variance (ANOVA) and Taguchi's optimization method, the following can be concluded from the present study.

- In the present experimental work, multi-response optimization problem has been solved by obtaining an optimal parametric combination, capable of producing high surface quality turned product in a relatively lesser time.
- Highest surface finish (lowest Ra) is obtained at a cutting speed of 200 m/min, feed rate of 0.2 mm/revolutions and a depth of cut of 0.5mm.
- The results of ANOVA for surface roughness show that feed rate is most significant parameter which affects the surface finish than other cutting parameters. The cutting speed and depth of cut are least significant parameters.
- The best settings of control factors (i.e cutting speed, feed rate and depth of cut) which influence the output parameters are determined through experiments.
- The results of Taguchi method shows that feed rate is most significant parameter which affects the surface finish than other cutting parameters. The cutting speed and depth of cut are least significant parameters.
- Satisfying results were obtained so that they may be used in future research work and industrial studies.

## 6. Scope for Future Work

- One can go for L27 orthogonal array Taguchi design or  $3^k$  full factorial design for obtaining greater result than the L9 orthogonal array.
- One can also use SYSTAT or SAS Software rather than using MINITAB for the Design of experiment.
- One can also use cutting force as an additional factor with addition to cutting speed, feed, depth of cut and make full factorial design of  $2^4$  or Full factorial three level design in form of  $3^4$  and can do optimization process.

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