

Research Article

An Experimental Study and Analysis of Surface Roughness in Wet Turning Operation of EN 353 Steel

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Abstract

The objective of this paper is to develop a taguchi optimization method for low surface roughness in terms of process parameters when turning the EN-353 steel on conventional lathe machine. Considering the process parameters as Depth of cut, Feed, Spindle Speed, Rake Angle & Pressurized Coolant Jet, a series of turning experiments were performed to measure surface roughness data. Taguchi orthogonal arrays, signal-to-noise(S/N) ratio, and analysis of variance (ANOVA) are used to find the optimal levels and the effect of the process parameters on surface roughness. Confirmation experiment with the optimal levels of process parameters was carried out in order to demonstrate the effectiveness of the taguchi method. It can be concluded that Taguchi method is very suitable in solving the surface quality problem of turned work pieces.

Keywords: EN353 steel, wet turning, Surface Roughness, Taguchi Method

1. Introduction

Surface finish has been one of the most important considerations in determining the machinability of materials. Surface roughness and dimensional accuracy are the important factors required to predict machining performances of any machining operations.

Optimizations of machining parameters are not only increases the utility for machining economics, but also the product quality increases to a great extent. In this context, an effort has been made to estimate the surface roughness using experimental data. Since turning is the primary operation in most of the production processes in the industry, surface finish of turned components has greater influence on the quality of the product.

Surface finish in turning has been found to be influenced in varying amounts by a number of factors such as feed rate, work material characteristics, work hardness, unstable built-up edge, cutting speed, depth of cut, cutting time, tool nose radius and tool cutting edge angles, stability of machine tool and work piece setup, chatter, and use of cutting fluids. To improve the efficiency of these turning processes, it is necessary to have a complete process understanding and model. It is impossible to find all the variables that impact surface roughness in turning

operations. In addition, it is costly and time consuming to discern the effect of the every variable on the output. In order to simplify the problem, one needs to eliminate or select specific variables that correspond to practical applications. Taguchi method consist of a plan of experiments with the objective of acquiring data in a controlled way, executing these experiments and analyzing data, in order to obtain information about the behavior of a given process. It uses orthogonal arrays to define the experimental plans and the treatment of the experimental results is based on the analysis of variance (ANOVA).

In the recent years many computer aided pulmonary nodules detection systems have been proposed and designed and in designing these systems image processing

2. Materials and Method

In this research work, emphasis laid to study the effect of five different parameters (Depth of cut, Feed, Spindle Speed, Rake Angle & Pressurized Coolant Jet) on the Surface Roughness of the turned specimens of EN353 using L16 Taguchi orthogonal design, the Turning Operations have been done 16 times followed by measurements of surface roughness of the workpieces in Sparko Engineering Workshop, Allahabad. The specimen workpiece were turned by Carbide cutting tool in wet cutting condition.

In proposed work, EN353 steel with carbon (0.14%), Nickel (1.5 %), Chromium (1 %) and Molybdenum (0.23 %) was selected for specimen material.

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Table: 2.1 Control Input Factors and their Levels

Factors	Level 1	Level 2
Depth of cut (mm)	0.5	1.0
Feed Rate (mm/rev)	0.16	0.80
Spindle Speed (rpm)	780	1560
Rake Angle (degree)	4 ⁰	7 ⁰
Pressurized Coolant Jet (bar)	0.5	1.0

Table: 2.2 Results of Experimental Trial Runs

Trial No.	Feed Rate (mm/rev)	Depth of cut (mm)	Spindle Speed (rpm)	Rake angle (degree)	Pressurised Coolant Jet(bar)	Surface Roughness (μm)	SN Ratio
1	0.16	0.5	780	4	0.5	72.90	-37.2546
2	0.16	0.5	780	7	1.0	103.00	-40.2567
3	0.16	1.0	780	4	1.0	75.00	-37.5012
4	0.16	1.0	780	7	0.5	105.00	-40.4238
5	0.16	0.5	1560	4	1.0	115.67	-41.2569
6	0.16	0.5	1560	7	0.5	180.11	-45.1108
7	0.16	1.0	1560	4	0.5	90.50	-39.1330
8	0.16	1.0	1560	7	1.0	46.90	-33.4235
9	0.80	0.5	780	4	1.0	86.20	-38.7101
10	0.80	0.5	780	7	0.5	148.80	-43.4521
11	0.80	1.0	780	4	0.5	42.50	-32.5678
12	0.80	1.0	780	7	1.0	56.70	-35.0717
13	0.80	0.5	1560	4	0.5	42.66	-32.6004
14	0.80	0.5	1560	7	1.0	110.00	-40.8279
15	0.80	1.0	1560	4	1.0	36.65	-31.2815
16	0.80	1.0	1560	7	0.5	158.80	-44.0170

Table 2.3: ANOVA Table for Means

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Feed Rate (mm/rev)	1	711.2	711.2	711.2	1.30	0.299
Depth of Cut (mm)	1	3818.9	3818.9	3818.9	6.95	0.039
Spindle Speed (rpm)	1	518.6	518.6	518.6	0.94	0.369
Rake Angle (degree)	1	7539.9	7539.9	7539.9	13.73	0.010
Pressurized Coolant Jet (bar)	1	2789.2	2789.2	2789.2	5.08	0.065
Depth of Cut (mm)* Pressurized Coolant Jet(bar)	1	1441.2	1441.2	1441.2	2.62	0.156
Spindle Speed (rpm)*Rake Angle (degree)	1	337.9	337.9	337.9	0.62	0.463
Spindle Speed (rpm)*Pressurized Coolant Jet(bar)	1	821.5	821.5	821.5	1.50	0.267
Rake Angle(degree)*Pressurized Coolant Jet(bar)	1	7266.3	7266.3	7266.3	13.23	0.000
Error	6	3294.9	3294.9	549.1		
Total	15	28539.5				

The values of the input process parameters for the Turning Operation are shown in table 1

The specimens were turned on the lathe machine in accordance with the experimental design and surface roughness was measured around the part with the

workpiece fixture and the measurements were taken across the lay, while the setup is a three-jaw chuck. The full length of the specimen (250 mm) was divided into 6 equal parts and the surface roughness measurements were taken of each 41.6 mm around each workpiece.

Table 2.4: ANOVA Table for Means

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Feed Rate (mm/rev)	1	15.666	15.666	15.666	2.24	0.185
Depth of Cut (mm)	1	42.413	42.413	42.413	6.07	0.049
Spindle Speed (rpm)	1	0.364	0.364	0.364	0.05	0.827
Rake Angle (degree)	1	65.116	65.116	65.116	9.32	0.022
Pressurized Coolant Jet (bar)	1	16.463	16.463	16.463	2.36	0.176
Depth of Cut (mm)* Pressurized Coolant Jet (bar)	1	28.884	28.884	28.884	4.13	0.088
Spindle Speed (rpm)*Rake Angle (degree)	1	2.203	2.203	2.203	0.32	0.595
Spindle Speed (rpm)*Pressurized Coolant Jet(bar)	1	8.870	8.870	8.870	1.27	0.303
Rake Angle(degree)*Pressurized Coolant Jet(bar)	1	58.591	58.591	58.591	8.39	0.027
Error	6	41.916	41.916	6.986		
Total	15	280.486				

Table 2.5: Response Table for SN Ratio

Level	Feed Rate	Depth of Cut	Spindle Speed	Rake Angle	Pressurized Coolant Jet
1	98.62	107.41	86.26	70.25	105.16
2	85.29	76.51	97.65	113.66	78.75
Delta	13.33	30.90	11.39	43.42	26.41
Rank	4	2	5	1	3

Table 2.6: Response Table for Means

Level	Feed Rate	Depth of Cut	Spindle Speed	Rake Angle	Pressurized Coolant Jet
1	-39.30	-39.93	-38.15	-36.29	-39.32
2	-37.32	-36.68	-38.46	-40.32	-37.29
Delta	1.98	3.26	0.30	4.03	2.03
Rank	4	2	5	1	3

From Table 2.5 and 2.6, the optimal levels of the Parameters for Turning Operation were **A₂, B₂, C₁, D₁ & E₂**

Signal-to-noise ratio (SNR) is utilized to measure the deviation of quality characteristic from the target.

In this experiment, the response is the surface roughness which should be minimized, so the desired SNR characteristic is in the category of smaller the better.

Table 2.5 shows the SNR of the surface roughness for each level of the factors. The difference of SNR between level 1 and 2 indicates that rake angle contributes the highest effect ($\Delta_{\max-\min} = 43.42$) on the surface roughness followed by depth of cut ($\Delta_{\max-\min} = 30.90$), pressurized coolant jet ($\Delta_{\max-\min} = 26.41$), feed Rate ($\Delta_{\max-\min} = 13.33$) and spindle speed ($\Delta_{\max-\min} = 11.39$). Similarly Table 2.6 shows the means of the surface roughness for each level of the factors. The difference of SNR between level 1 and 2 indicates that rake angle contributes the highest effect ($\Delta_{\max-\min} = 4.03$) on the surface roughness followed by depth of cut ($\Delta_{\max-\min} = 3.26$), pressurized coolant jet ($\Delta_{\max-$

$\Delta_{\max-\min} = 2.03$), feed Rate ($\Delta_{\max-\min} = 1.98$) and spindle speed ($\Delta_{\max-\min} = 0.30$).

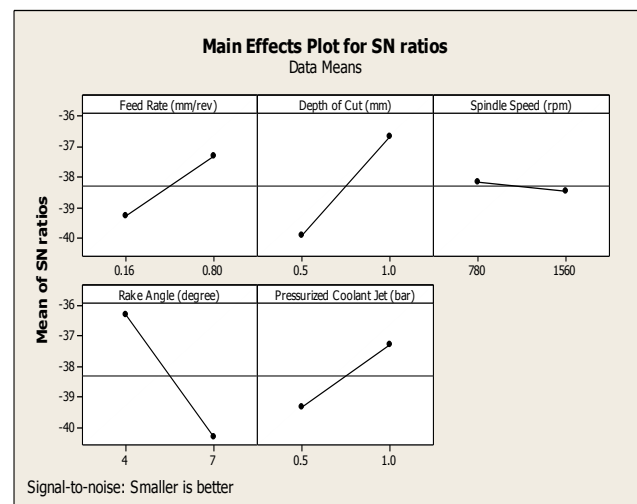


Fig 1 Main Effect Plot for SN Ratio

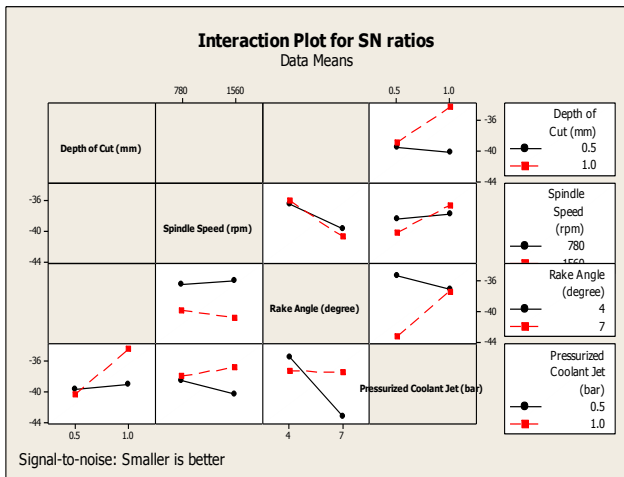


Fig 2 Interaction Plot for SN Ratio

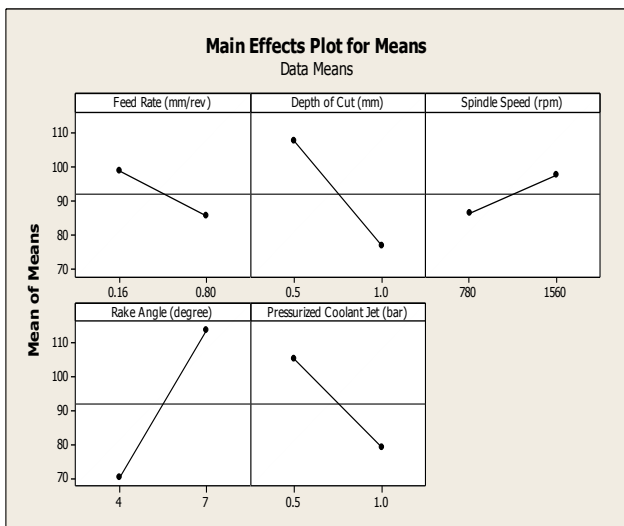


Fig 3 Main Effect Plot for Means

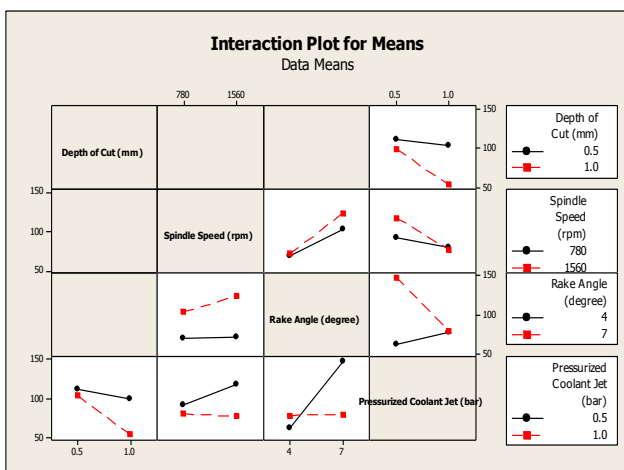


Fig 4 Interaction Plot for Means

η_p (SN Ratio)
 $= -38.31 + [(-37.2 - (-38.31))] + [-36.68 - (-38.31)] + [-38.15 - (-38.31)] + [-36.29 - (-38.31)] + [-37.29 - (-38.31)]$

$= -32.5$

η_p (Means of Surface Roughness)
 $= 91.955 + (85.29 - 91.955) + (76.51 - 91.955) + (86.26 - 91.955) + (70.25 - 91.955) + (78.75 - 91.955)$
 $= 55.65$

Table 2.7: Results for Confirmation Test Trial Runs of Turning Operation for Surface Roughness for the Combination of Optimal Levels of Factors

Specimen	Depth of Cut (mm)	Feed Rate (mm/rev)	Spindle Speed (rpm)	Rake Angle (degrees)	Pressurized Coolant Jet (bar)	Surface Roughness (μ_m)
1	1	0.8	780	70	1	28.34.
1	1	0.8	780	70	1	28.31
1	1	0.8	780	70	1	28.29

3. Result & Discussion

Comparison of the F values of ANOVA Table 2.3 of Surface Roughness with the suitable F values of the Factors ($F_{0.05;1;10} = 4.96$) respectively shows that the all the factors except depth of cut and rake angle were found to be insignificant. While the interaction of rake angle and pressurized coolant jet was the only interaction found to be significant out of all the considered interactions. From Table 2.5, Fig 3, optimal levels of the parameters for Surface Roughness are second level of Depth of Cut (1.0 mm), second level of Feed Rate (0.8 mm/rev) and first level of Spindle Speed (780 rpm), second level of Rake angle (7°) and second level of Pressurized Coolant Jet (1.0 bar).

So the optimal combination of the factors is found in 12th trial in Table No.2.2 gives the optimum result.

4. Conclusions

- A parameter designs yielded the optimum condition of the controlled parameters, as well as a predictive equation in each case and comparative study was done. A confirmation tests was then performed which indicated that the selected parameters and predictive equation were accurate to within the limits of the measurement instrument.
- Therefore the above results can be recommended to get the lowest surface roughness for further studies.
- In the current research work, the material used is EN353 with 0.14% carbon. The experimental Work can also be done for other materials having more hardness to see the effect of parameters on Surface Roughness.
- In each case interactions of the different levels of the

factors can be included and study can be extended.

- The experimental work and research can be extended by different tool geometry, different types of coolants etc. as factors.

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