IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 8, Issue 4 (Sep. - Oct. 2013), PP 33-38
www.iosrjournals.org

An Experimental Study of the Effect of Control Parameters on the Surface Roughness in Turning Operation of EN 353 Steel

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Abstract: *Surface quality is one of the specified manufacturer requirements for machined parts. There are many parameters that have an effect on surface roughness, but those are difficult to quantify adequately in finish turning operation such as cutting speed, feed rate, and depth of cut are known to have a large impact on surface quality. The Taguchi method is one of the statistical tools, to investigate influence of surface roughness by cutting parameters such as cutting speed, feed and depth of cut. The Taguchi process helps to select or to determine the optimum cutting conditions for turning process. Many researchers developed many mathematical models to optimize the cutting parameters to get lowest surface roughness by turning process. The Taguchi design of experiments was used for optimizing quality and performance output of manufacturing processes.*
Key words: *turning operation, Taguchi Method, ANOVA, S/N Ratio*

I. Introduction

A manufacturing engineer is often expected to utilize experience and published shop guidelines for determining the proper machining parameters to achieve a specified level of surface roughness. This must be done in a timely manner to avoid production delays, effectively to avoid defects, and the produced parts monitored for quality. Therefore, in this situation, it is prudent for the engineer or technician to use past experience to select parameters which will likely yield a surface roughness below that of the specified level, and perhaps make some parameter adjustments as time allows or quality control requires. A more methodical, or experimental, approach to setting parameters should be used to ensure that the operation meets the desired level of quality with given noise conditions and without sacrificing production time. Rather than just setting a very low feed rate to assure a low surface roughness, for example, an experimental method might determine that a faster feed rate, in combination with other parameter settings, would produce the desired surface roughness.

II. Materials and Method

. In the current research work, in order 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.

The values of the input process parameters for the Turning Operation are as under:

Table: 2.1 Control Input Factors and their levels

Factors	Level 1	Level 2
Depth of cut (mm)	0.5	1.0
Feed (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

In this experiment, the assignment of factors was carried out using MINITAB 15 Software. Using the L16 orthogonal array the trial runs of turning operations have been conducted on Lathe Machine.

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 2.2: Results of Experimental Trial Runs for Turning Operation

Trial No.	Depth of Cut (mm)	Feed Rate (mm/rev)	Spindle Speed (rpm)	Rake Angle (degree)	Pressurized Coolant Jet (bar)	Surface Roughness (µm)	SN Ratio
01	0.5	0.16	780	4^0	0.5	73.00	-37.2665
02	0.5	0.16	780	7^0	1.0	103.00	-40.2567
03	1.0	0.16	780	4^0	1.0	75.09	-37.5116
04	1.0	0.16	780	7^0	0.5	105.00	-40.4238
05	0.5	0.16	1560	4^0	1.0	115.67	-41.2644
06	0.5	0.16	1560	7^0	0.5	180.11	-45.1108
07	1.0	0.16	1560	4^0	0.5	90.60	-39.1426
08	1.0	0.16	1560	7^0	1.0	46.90	-33.4235
09	0.5	0.80	780	4^0	1.0	86.40	-38.7303
10	0.5	0.80	780	7^0	0.5	148.80	-43.4521
11	1.0	0.80	780	4^0	0.5	42.90	-32.6491
12	1.0	0.80	780	7^0	1.0	56.80	-35.0870
13	0.5	0.80	1560	4^0	0.5	42.66	-32.6004
14	0.5	0.80	1560	7^0	1.0	110.10	-40.8357
15	1.0	0.80	1560	4^0	1.0	36.65	-31.2815
16	1.0	0.80	1560	7^0	0.5	158.00	-44.0225

Table 2.3: ANOVA Table for Means

Parameters	DF	SS	MS	F	P
Depth of Cut	1	3810	3810	2.28	0.175
Feed Rate	1	704	704	0.42	0.537
Spindle Speed	1	513	513	0.31	0.597
Rake Angle	1	7510	7510	4.49	0.072
Pressurized Coolant Jet	1	2792	2792	1.67	0.237
Feed rate*Pressurized Coolant Jet	1	1	1	0.00	0.978
Depth of Cut*Spindle Speed	1	254	254	0.14	0.925
Depth of cut*Pressurized Coolant Jet	1	7	7	0.00	0.382
Error	7	11704	11704	1672	
Total	15	28505			

Table 2.4: ANOVA Table for Signal to Noise Ratio

Parameters	DF	SS	MS	F	P
Depth of Cut	1	42.17	42.17	2.67	0.146
Feed Rate	1	15.49	15.49	0.98	0.355
Spindle Speed	1	0.33	0.33	0.02	0.889
Rake Angle	1	64.66	64.66	4.10	0.083
Pressurized Coolant Jet	1	16.56	16.56	1.05	0.340
Feed rate* Pressurized Coolant Jet	1	0.45	0.45	0.03	0.870
Depth of Cut *Spindle speed	1	0.27	0.27	0.02	0.899
Depth of cut* Pressurized Coolant Jet	1	29.14	29.14	1.85	0.216
Error	7	110.52	15.79		
Total	15	279.60			

Table 2.5: Response Table for Signal-to-Noise ratio of Surface Roughness

Level	Depth of Cut (A)	Feed Rate (B)	Spindle Speed (C)	Rake Angle (D)	Pressurized Coolant Jet (E)
1	-39.94	-39.30	-38.17	-36.31	-39.33
2	-36.69	-37.33	-38.46	-40.33	-37.30
Delta (Δ_{max} -Δ_{min})	3.25	1.97	0.29	4.02	2.03
Rank	2	4	5	1	3

From Table 2.5, optimal levels of the Parameters for Turning Operation were $\mathbf{A_2}$, $\mathbf{B_2}$, $\mathbf{C_1}$, $\mathbf{D_2}$ & $\mathbf{E_2}$
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 3 indicates that rake angle contributes the highest effect ($\Delta_{max-min}$ = 4.07) on the surface roughness followed by depth of cut ($\Delta_{max-min}$ = 3.25), pressurized coolant jet ($\Delta_{max-min}$ = 2.12), feed Rate ($\Delta_{max-min}$ = 1.95) and spindle speed ($\Delta_{max-min}$ = 0.30).

Therefore the Predicted value of S/N Ratio for surface roughness

$\eta_{p\ (Surface\ Roughness)}$
= -38.305+ [(-37.33-(-38.305)] + [-36.68-(-38.305)] +
[-38.15-(-38.305)] + [-36.29-(-38.305)] + [-37.22-(-38.305)]

= **-32.45**

$\mu_{p\ (Surface\ Roughness)}$
=91.95+ (85.24-91.95) + (76.56-91.95) + (86.04-91.95) + (70.14-91.95) + (78.14-91.95)
=**28.32**

III. Results and 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 rake angle were found to be insignificant.

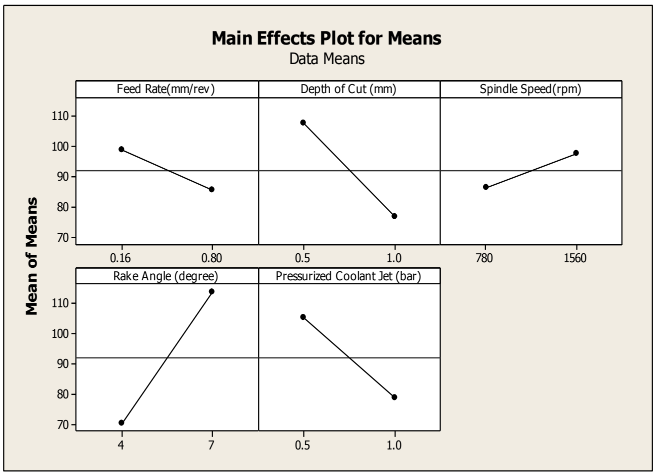

Fig. 3.1 Main Effect Plot for Means

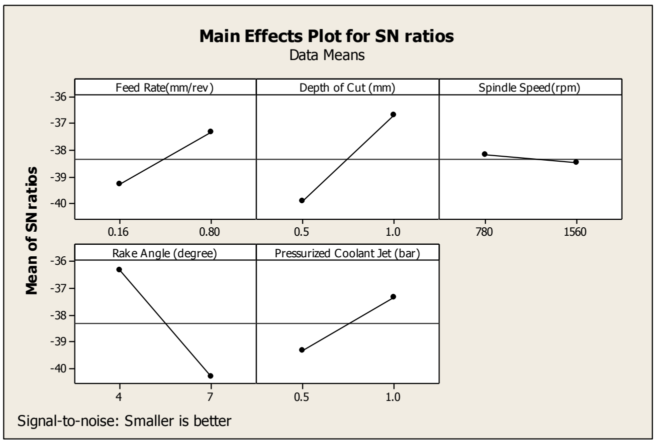

Fig. 3.2. Main Effect Plot for SN Ratio

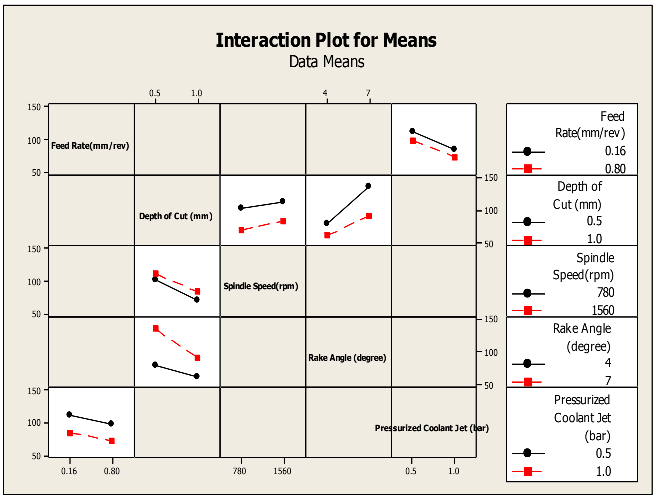

Fig. 3.3. Interaction Plot for Means

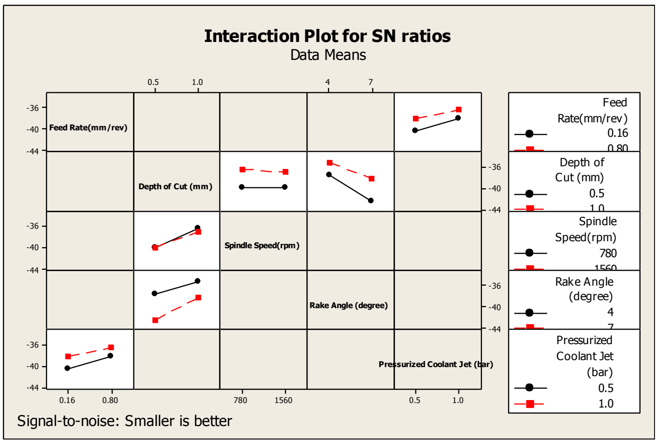

Fig. 3.4. Interaction Plot for SN Ratio

Table No. 2.5 shows the results of Signal-to-Noise ratio for Surface Roughness.

From Table 2.5, Fig 3.1 and Fig 3.2, 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 (7^0) 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.

Table 2.6: 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	0.8	780	7^0	1.0	28.34.
1	1.0	0.8	780	7^0	1.0	28.31
1	1.0	0.8	780	7^0	1.0	28.29

- 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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