Optimization of Process Parameters of Turning Operation of EN 24 Steel using Taguchi Design of Experiment Method

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***Abstract*— Surface finish is one of the vital concerns during machining of various materials in the machining operations. Therefore it is very essential for controlling the required surface quality to have the choice of optimized cutting parameters. The present experimental study is concerned with the optimization of cutting parameters (depth of cut, feed rate, spindle speed) in wet turning of EN24 steel (0.4% C) with hardness 40±2 HRC. In the present work, turning operations were carried out on EN24 steel by carbide P-30 cutting tool in wet condition and the combination of the optimal levels of the parameters was obtained. The Analysis of Variance (ANOVA) and Signal-to-Noise ratio were used to study the performance characteristics in turning operation. The results of the analysis show that none of the factors was found to be significant. Taguchi method showed that feed rate followed by depth of cut and spindle speed was the combination of the optimal levels of factors while turning EN24 steel by carbide cutting tool. The results obtained by this research will be useful to other similar type of study and can be helpful for further research on tool vibrations, cutting forces etc.**

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***Index Terms*— ANOVA, SN Ratio, surface roughness, taguchi methodology**

I. Introduction

The machinability of the materials is determined by surface finish. Surface roughness is an important measure of product quality since it greatly influences the performance of mechanical parts as well as production cost. Optimization of machining parameters not only increases the utility for machining economics, but also the product quality increases to a great extent. EN24 is a high quality, high tensile, alloy steel and combines high tensile strength, shock. EN24 is most suitable for the manufacture of parts such as heavy-duty axles and shafts, gears, bolts and studs. EN24 is capable of retaining good impact values at low temperatures[2]. Since Turning is the primary operation in most of the production process in the industry, surface finish of turned components has greater influence on the quality of the product[3].

Surface finish in turning has been found to be influenced in varying amounts by a number of factors such as feed rate, work hardness, unstable built up edge, speed, depth of cut, cutting time, use of cutting fluids etc[4]. The three primary process parameters in any basic Turning operation are speed, feed, and depth of cut. Speed always refers to the spindle and the work piece. Feed is the rate at which the tool advances along its cutting path. Depth of cut is the thickness of the material that is removed by one pass of the cutting tool over the workpiece[5].

II. Materials and Methods

In the present work, L9 Taguchi orthogonal design[6] was used in order to study the effect of three different parameters (Depth of cut, Feed & Spindle Speed) on the Surface Roughness of the turned specimens of EN24 using, the Turning Operations and measurements of surface roughness have been done 9 times on the workpieces. The turning of workpieces was done by Carbide cutting tool in wet cutting condition. For this purpose a coolant was used.

In proposed work, EN24 steel with carbon (0.4%), 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 I
Details of the Turning Operation

Factors	Level 1	Level 2	Level 3
Depth of Cut (mm)	0.5	1.0	1.5
Feed Rate (mm/rev)	1.21	1.81	3.63
Spindle Speed	780	1560	2340

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TABLE II
RESULTS OF EXPERIMENTAL TRIAL RUNS

Depth of Cut (mm)	Feed Rate (mm/rev)	Spindle Speed (rpm	Surface Roughness (µm)	S/N Ratio
0.5	3.63	780	20.8	-26.36
0.5	1.81	1560	25.00	-27.95
0.5	1.21	2340	4.16	-12.38
1.0	3.63	1560	24.167	-27.66
1.0	1.81	2340	20.83	-26.37
1.0	1.21	780	24.16	-27.66
1.5	3.63	2340	21.58	-26.68
1.5	1.81	780	6.7	-16.52
1.5	1.21	1560	14.16	-23.02

The workpieces were turned 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 total length of the workpiece (250 mm) was divided into 6 parts and the surface roughness measurements were taken of each 41.6 mm around each workpiece.

TABLE III
ANOVA TABLE FOR MEANS

Parameter	DF	SS	MS	F	P
Depth of Cut	2	69.12	34.56	0.35	0.420
Feed Rate	2	170.92	56.79	0.57	0.636
Spindle Speed	2	49.16	24.58	0.25	0.801
Error	2	198.31	99.16		
Total	8	487.52			

TABLE IV
ANOVA TABLE FOR SIGNAL TO NOISE RATIO

Parameter	DF	SS	MS	F	P
Depth of Cut	2	14.84	7.42	0.15	0.869
Feed Rate	2	109.95	36.59	0.75	0.573
Spindle Speed	2	29.56	14.78	0.30	0.769
Error	2	98.19	49.10		
Total	8	252.5			

In this experiment, the assignment of factors was carried out using MINITAB-15 Software. Using the L9 orthogonal array the trial runs have been the conducted on Lathe Machine for turning operations.

TABLE V
ANOVA TABLE FOR MEANS

Level	Depth of Cut	Feed Rate	Spindle Speed
1	-22.32	-25.69	-23.51
2	-27.23	-18.95	-26.21
3	-22.07	-26.90	-21.81
Delta (max-min)	5.16	7.95	4.40
Rank	2	1	3

The predicted value of S/N ratio using the optimal level of the design parameters can be calculated:

$$\eta_{opt} = \eta_m + \sum_{i=0}^{o} (\eta_i - \eta_m) \quad (1)$$

Where η_m is the total mean S/N ratio, η_i is the mean S/N ratio at optimum level and 'o' is the number of main design parameter that effect quality characteristic.

η_p (Surface Roughness)
= -23.87+ [-18.95-(-23.87)] + [-21.81-(-23.87)] + [-22.07-(-23.87)] =-15.09

III. RESULTS

Comparing the F values of ANOVA Table IV of Surface Roughness with the suitable F values of the Factors ($F_{0.05;2;2}$ = 19.0) respectively shows that the all these factors are insignificant.

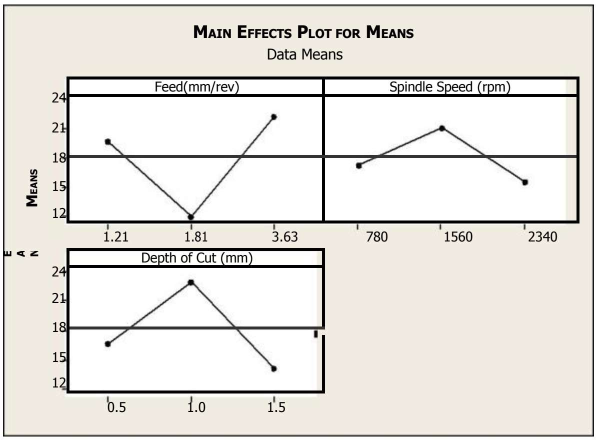

Fig. 1: Main Effects Plot for Means

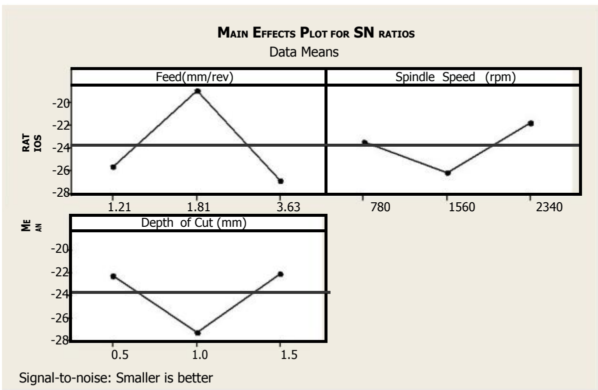

Fig. 2: Main Effects Plot for S/ N ratios

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

From Table V, Fig. 1 and Fig. 2, optimal parameters for Surface Roughness were third level of Depth of Cut (A_3), second level of Feed (B_2) and third level of Spindle Speed (C_3).

Therefore the combination of the factors is not found in any given trial in Table II gives the optimum result.

Three confirmation tests were conducted to validate the

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result using the Combination of the optimal levels of the factors.
Table VI shows the result of the three confirmation tests.

TABLE VI
RESULTS OF CONFIRMATION TESTS OF THE OPTIMAL LEVELS OF THE PARAMETERS

Depth of Cut (mm)	Feed Rate (mm/rev)	Spindle Speed (rpm)	Surface Roughness (μm)
1.5	1.81	2340	20.22
1.5	1.81	2340	20.17
1.5	1.81	2340	20.06

The Continuous reduction in the value of the Surface roughness implies that the above trial run will always give the optimum result.

IV. CONCLUSIONS

- A parameter designs yielded the optimum condition of the controlled parameters, as well as a predictive equation was used. 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 this research work, the material used is EN24 with 0.4% carbon. The experimentation 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 also be included and study can be extended.
- The research can be extended by using tool nose radius etc. as factors.

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