Optimization of CNC Turning for EN36 Alloy Steel Using Coated Carbide insert

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Abstract: **This study applies Taguchi's design of experiment methodology for optimization of process parameters in CNC Turning of EN36 Alloy Steel using coated carbide. Experiments have been carried out based on L27 orthogonal array with three process parameters namely cutting speed, feed and depth of cut for surface roughness, material removal rate and cylindricity. Experiments were conducted under dry environment. The optimal parameter combinations for surface roughness, material removal rate and cylindricity were found out. ANOVA was performed to know which input parameter has most significant effect on performance measures.**

Keywords: CNC Turning, EN36 Alloy Steel, Taguchi, ANOVE

I. INTRODUCTION

Turning is basic and most widely used cutting operation in metal cutting industries [1]. Modern industries strive hard to achieve improved quality of product and this can be achieved by selection of proper material and method [2]. S.J. Raykar et.al [3]The study optimized the cutting parameters for high speed turning of Al7075, were grey relational analysis has been used for multi-optimization. The recommended cutting parameters were 200 m/min speed, 0.1 mm/rev feed, and 0.5 mm depth of cut with coated carbide insert in dry condition. M. Murali Mohan et.al [4] the optimization of EN36 Alloy steel was performed using RSM. Results showed that temperature is mainly affected by depth of cut while surface roughness by feed. Sayak Mukherjee et.al [5] studied effect of cutting parameters on material removal rate was studied. An optimum combination was obtained and the study was also useful for computer aided process planning. Shreemony kumar Nayak et.al [6] paper aims at investigating influence of different cutting parameters on different performance measures in dry turning of AISI304 using ISO P30 uncoated cemented carbide cutting tool. Optimum parametric combinations were found out for different responses. Even attempt was made to simultaneously optimize machining parameters using grey relational analysis. 88.76% of improvement was found in GRG. Sundrendra Kumar Saini et.al [7] in this research work CNC Turning of Al8011 is performed using carbide inserts. The optimum sets as well as combined effect were estimated using Taguchi-fuzzy application. Analysis showed that feed is the most significant process parameter followed by depth of cut and cutting speed.

B. Singarvel et.al [8] analyzed, optimization is performed using taguchi based utility concept coupled with principal component analysis turning of EN25 steel with PVD and CVD coated tools. Results showed that principle component analysis is successfully employed for estimation of weight factors. The result of ANOVA shows that coated tool is most significant parameter followed by cutting speed. R. Deepak Joel Johnson et.AL [9] an effort has been made to reduce the quantity of cutting fluid used. The optimization of cutting parameters and fluid application parameters was done for turning of OHNS steel with minimal cutting fluid application using taguchi technique. The results clearly indicated that minimal cutting fluid application enhanced the cutting performances by improving surface finis. Harsh Y Valera et.al [10] presents experimental study of power consumption and surface roughness for turning of EN31 alloy steel. Result showed that all cutting parameters significantly affect the responses. Ashok Kumar Sahoo et.al [11] studied taguchi DOE and regression analysis for optimization of process parameters in turning AISI 1040 steel using coated carbide insert under dry condition. L9 orthogonal array was used. Optimum parameter combinations were found. Further grey relational analysis combines with taguchi method has been proposed. Results show good agreement between estimated value and experimental value. The improved grey relational grade is found to be 0.284. B. C. Routaru et. al [12] made an attempt has been made to optimize the surface roughness prediction model using genetic algorithm to find optimum cutting parameters [12]

II. MATERIAL

The work piece material selected for this study was EN36 Alloy steel which is widely used in disc wheels, grooved parts, and gears, heavy duty gears for aircrafts, heavy vehicles and automobile parts. Workpiece used was a cylindrical bar having dimensions Ø34 mm x 90 mm. Chemical composition was checked at Material test Laboratory, Mumbai.

Table 1: Chemical composition of EN36 Alloy steel (%)

C	Si	Mn	P	S	Cr	Mo	Ni
0.1430	0.2200	0.4100	0.0260	0.0180	0.7900	0.1900	3.2800

III METHODOLOGY

Taguchi's method is one of the effective experimentation techniques in improving quality and cutting down cost at same time. In Taguchi's method, quality is measured by deviation of a characteristic from its target value. A loss function is developed for this deviation. Since the elimination of noise factors is impractical and often impossible, the taguchi method seeks to minimize the effect of noise and to determine the optimal level of important controllable factors based on concept of robustness. Taguchi method uses a special design of orthogonal array to study the entire parameters space with only a small number of experiments. ANOVA was performed to find the most significant factor that affect response.

In current study "Smaller-the- better" characteristics is used for Surface roughness and Cylindricity whereas "Higher- the-better" characteristics is used for Material removal rate.

The equations for calculating S/N ratios for as follows:

1. "Lower-the-better"

$$S/N_{LB} = -10\log\frac{1}{n}\sum_{i=1}^{n} Y^2 \quad (1)$$

2. "Higher-the-better"

$$S/N_{HB} = -10\log\frac{1}{n}\sum_{i=1}^{n} \frac{1}{Y^2} \quad (2)$$

IV EXPERIMENTAL SETUP

Figure.1 shows experimental setup for machining EN36 Alloy steel using coated carbide insert. Turning experiment was conducted using Feeler CNC Lathe FTC-20. All the experiments were conducted under dry environment. Coated carbide insert was used as cutting tool with ISO Coding TNMG160408MP and with tool holder PTLNR2020. All experimental runs were carried out under dry environment.

The experiment was carried out with out with controllable 3-level factors and 3 response variable. The present paper deals with 3 process parameters i.e. , Cutting speed, Feed and Depth of cut and 3 response factors, Surface roughness (Ra), Material Removal Rate (MRR) and Cylindricity (Ø).

Based on Taguchi's design of experiment and orthogonal array L27, total 27 experiments were carried out. Table 2 shows process parameters and their levels.

Figure.1: Photographic view of experimental setup for machining

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Table 2: Process Parameters and their levels

Sr.no	Factors	Level 1	Level 2	Level 3
1	Cutting speed (V_c) (m/min)	140	150	160
2	Feed (f) (mm/rev)	0.18	0.20	0.22
3	Depth of cut (a_p) (mm)	0.5	1	1.5

V. RESULTS AND DISCUSSION

All twenty-seven experimental runs are tabulated in Table 3 along with input parameters setting and experimental results. Reading for respective performance measure was taken. Mitutoya surface roughness was used for measurement of surface roughness (Ra). Cylindricity was measured using CMM.

Table 4 shows experimental results and S/N ratios for Ra, MRR and Cylindricity

Table 3: Taguchi L27 Orthogonal Array for experimental runs and results

Expt no.	Process parameters			Experimental results		
	V_c (m/min)	f (mm/rev)	a_p (mm)	Ra (µm)	MRR (g/min)	Ø (mm)
1	140	0.18	0.5	1.461	10.435	0.0192
2	140	0.18	1	1.498	41.739	0.0181
3	140	0.18	1.5	1.481	73.043	0.0127
4	140	0.20	0.5	1.690	28.571	0.0243
5	140	0.20	1	1.620	57.143	0.0205
6	140	0.20	1.5	1.654	85.714	0.0175
7	140	0.22	0.5	1.930	18.000	0.0193
8	140	0.22	1	1.937	60.000	0.0183
9	140	0.22	1.5	1.907	96.000	0.0155
10	150	0.18	0.5	1.161	16.364	0.0221
11	150	0.18	1	1.256	54.545	0.0201
12	150	0.18	1.5	1.261	87.273	0.0185
13	150	0.20	0.5	1.387	24.000	0.0279
14	150	0.20	1	1.422	54.000	0.0245
15	150	0.20	1.5	1.310	96.000	0.0211
16	150	0.22	0.5	1.497	25.263	0.0235
17	150	0.22	1	1.645	63.158	0.0219
18	150	0.22	1.5	1.491	101.053	0.0186
19	160	0.18	0.5	1.112	22.857	0.0183
20	160	0.18	1	1.285	51.429	0.0181
21	160	0.18	1.5	1.097	91.429	0.0141
22	160	0.20	0.5	1.307	25.263	0.0237
23	160	0.20	1	1.390	69.474	0.0224
24	160	0.20	1.5	1.458	83.000	0.0186
25	160	0.22	0.5	1.596	54.000	0.0209
26	160	0.22	1	1.667	73.333	0.0184
27	160	0.22	1.5	1.643	106.667	0.0162

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Table 4: Experimental results and S/N ratios for Ra, MRR and Ø

Expt no.	Experimental results			S/N Ratios		
	Ra (µm)	MRR (g/min)	Ø (mm)	Ra	MRR	Ø
1	1.461	10.435	0.0192	-3.29300	20.3697	34.3340
2	1.498	41.739	0.0181	-3.51024	32.4109	34.8464
3	1.481	73.043	0.0127	-3.41110	37.2716	37.9239
4	1.690	28.571	0.0243	-4.55773	29.1186	32.2879
5	1.620	57.143	0.0205	-4.19030	35.1392	33.7649
6	1.654	85.714	0.0175	-4.37071	38.6611	35.1392
7	1.930	18.000	0.0193	-5.71115	25.105	34.2889
8	1.937	60.000	0.0183	-5.74259	35.5630	34.7510
9	1.907	96.000	0.0155	-5.60701	39.6454	36.1934
10	1.161	16.364	0.0221	-1.29664	24.2776	33.1122
11	1.256	54.545	0.0201	-1.97979	34.7352	33.9361
12	1.261	87.273	0.0185	-2.01430	38.8176	34.6566
13	1.387	24.000	0.0279	-2.84153	27.6042	31.0879
14	1.422	54.000	0.0245	-3.05799	34.6479	32.2167
15	1.310	96.000	0.0211	-2.34543	39.6454	33.1544
16	1.497	25.263	0.0235	-3.50444	28.0498	32.5786
17	1.645	63.158	0.0219	-4.32332	36.0086	33.1911
18	1.491	101.053	0.0186	-3.46955	40.0910	34.6097
19	1.112	22.857	0.0183	-0.92210	27.1804	34.7510
20	1.285	51.429	0.0181	-2.17806	34.2241	34.8464
21	1.097	91.429	0.0141	-0.80413	39.2216	37.0156
22	1.307	25.263	0.0237	-2.32551	28.0498	32.5050
23	1.390	69.474	0.0224	-2.86030	36.8364	32.9950
24	1.458	83.000	0.0186	-3.27515	38.3316	34.6067
25	1.596	54.000	0.0209	-4.06066	34.6479	33.5917
26	1.667	73.333	0.0184	-4.43871	37.3060	34.7036
27	1.643	106.667	0.0162	-4.31275	40.5606	35.9176

The optimal para,eteric combinations for each performance measure were found by main effect plots for S/N Ratios.
The level of parameter with highest S/N ratio gives the optimal level.

Figure 2 shows main effect plot for Ra. The optimal prameteric combination for Ra is V_c2f1a_p1. Thus, optimum parameter value for minimum surface roughness is 150 m/min cutting speed, feed 0.18 mm/rev and depth of cut is 0.5 mm. Further ANOVA was performed. Table 5 shows ANOVA for Ra.

The experimental results were analyzed using analysis of variance (ANOVA) for identifying the significant factors affecting the performance measures. The results of ANOVA for Ra are shown in Table 7.This analysis was carried out for a significance level of 0.05 (Confidence level of 95 %). The ANOVA result shows that, the F-value for the cutting speed and feed is larger than that of the depth of cut i.e. the largest contribution to the workpiece surface roughness or finish is due to the feed rate. Feed rate (the most significance factor) contributed 55.06 % for Ra.

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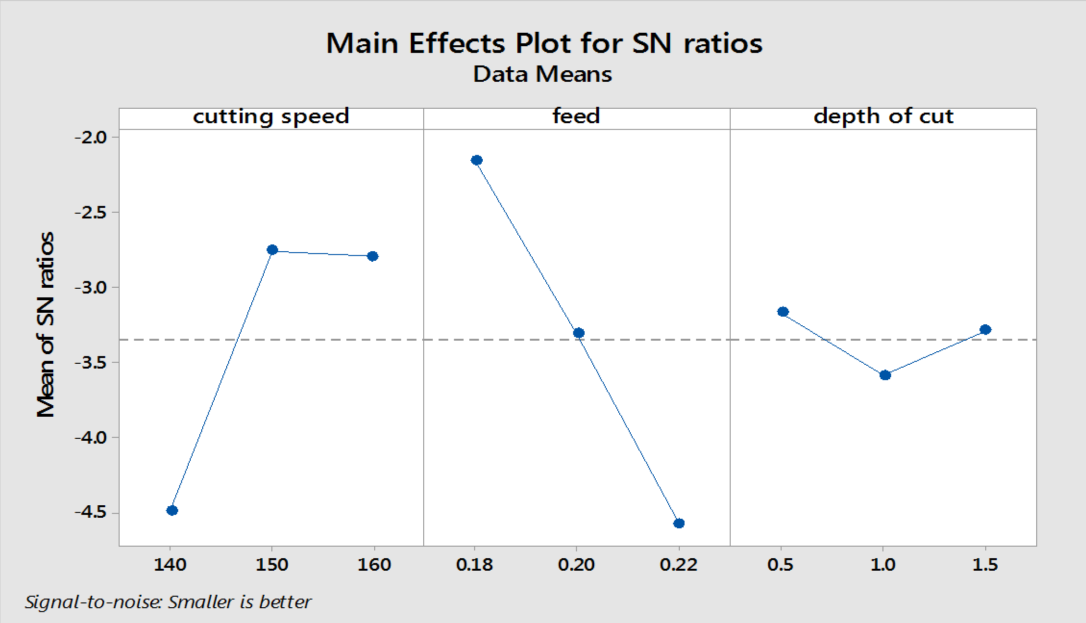

Figure 2: Main effects plot for S/N ratio of Ra

Table 5: ANOVA for Ra

Factors	DF	SS	MS	F-value	P-value	Contribution%
Cutting speed	2	0.53508	0.267542	77.24	0.000	38.53
Feed	2	0.76470	0.382350	110.39	0.000	55.06
Depth of cut	2	0.01985	0.009924	2.87	0.081	1.42
Error	20	0.06927	0.003464			4.99
Total	26	1.38890				100

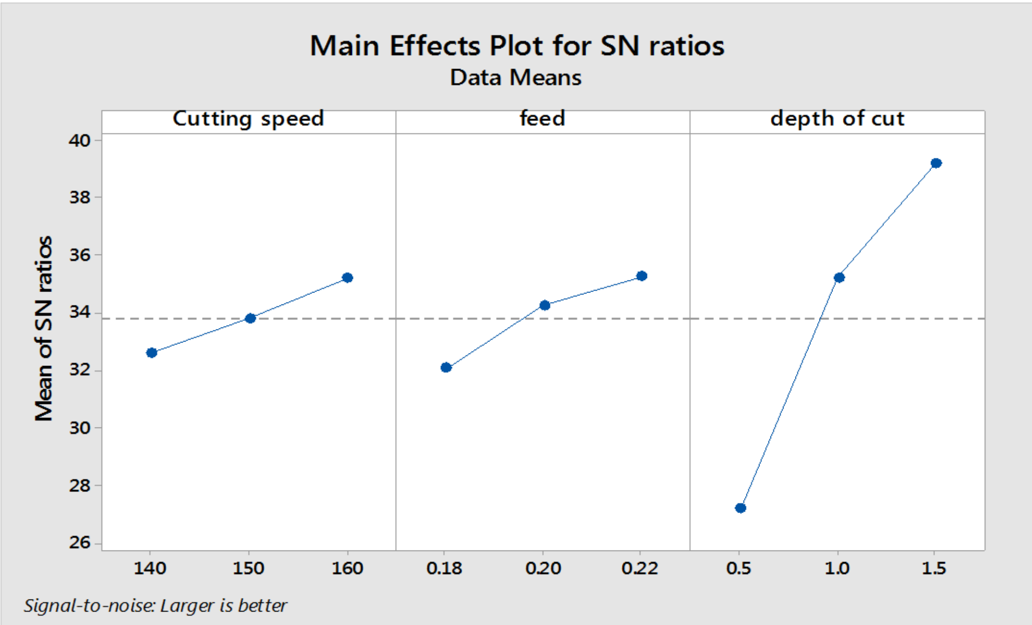

Figure.3: Main effects plot for S/N ratio of MRR

Figure 3 shows main effect plot for MRR. The optimal prameteric combination for MRR is V_c3f3a_p3. Thus, optimum parameter value for minimum surface roughness is 160 m/min cutting speed, feed 0.22 mm/rev and depth of cut is 1.5 mm. Further ANOVA was performed. Table 6 shows ANOVA for MRR. Table 6 shows the realized significance levels, associated with the F-tests for each source of variation. The ANOVA result shows that the F-value for the depth of cut and feed is larger than the cutting speed i.e. the largest contribution to the MRR is due the depth of cut. Depth of cut contributes 83.73% for MRR.

Table 6: ANOVA for MRR

Factors	DF	SS	MS	F-value	P-value	Contribution%
Cutting speed	2	634.2	317.08	7.08	0.005	2.83
Feed	2	1222.8	611.41	13.65	0.000	5.45
Depth of cut	2	19696.6	9848.29	219.89	0.000	87.73
Error	20	895.8	44.79			3.99
Total	26	22449.3				100

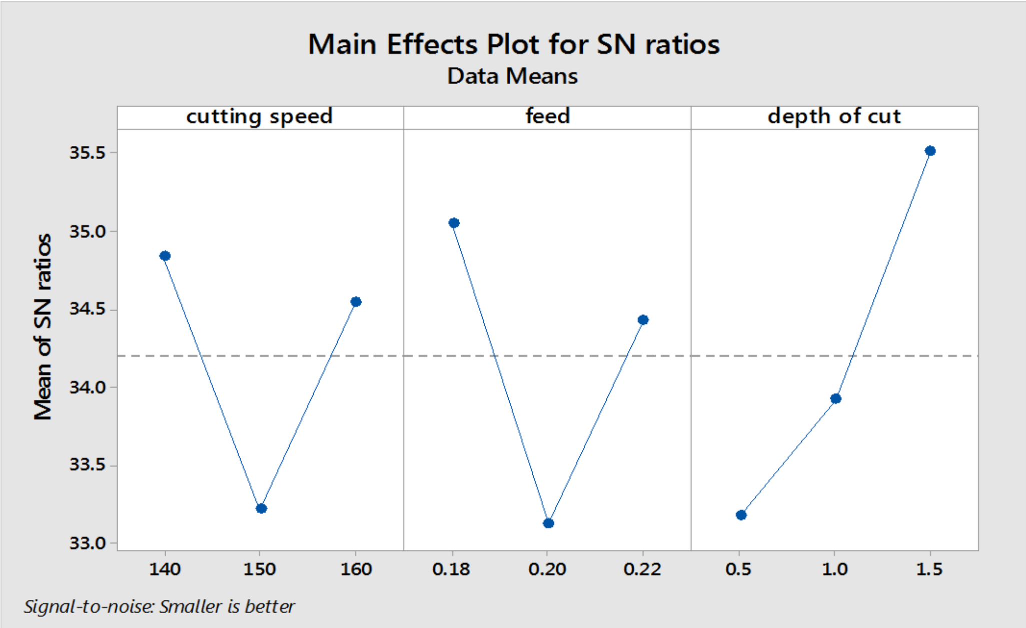

Figure 4: Main effect plot for S/N ratios of Cylindricity

Figure 3 shows main effect plot for Cylindricity. The optimal prameteric combination for Cylindricity is V_c1f1a_p3. Thus, optimum parameter value for minimum surface roughness is 140 m/min cutting speed, feed 0.18 mm/rev and depth of cut is 1.5 mm. Further ANOVA was performed. In Table 7, the ANOVA result shows that the F-value for the feed rate and depth of cut is larger than that of the cutting speed. The largest contribution to the cylindricity is of depth of cut i.e. 42.03%. The percent contribution of the second most significance factor i.e. feed was found to be 30.85%.

Table 7: ANOVA for Cylindricity

Factors	DF	SS	MS	F-value	P-value	Contribution%
Cutting speed	2	0.000069	0.000035	61.14	0.00	23.39
Feed	2	0.000091	0.000046	80.45	0.000	30.85
Depth of cut	2	0.0000124	0.000062	109.23	0.000	42.03
Error	20	0.000011	0.000001			3.73
Total	26	0.00295				100

VI CONCLUSION

In this study, the effects of cutting speed, feed and depth of cut on surface roughness, material removal rate and cylindricity during CNC Turning of EN36 Alloy Steel were investigated using Taguchi's experimental design. The final conclusion arrived, at the end of this work are as follows:

- From this analysis, the optimal parametric combinations for Ra, MRR and Cylindricity were found.
- The optimal parametric combinations for Ra, MRR and Cylindricity is V_c2f1a_p1, V_c2f2a_p2, V_c1f1a_p3 respectively.
- ANOVA was performed; Ra is most significantly affected by feed rate whereas MRR and Cylindricity is most significantly affected by Depth of cut.
- Thus Taguchi method is powerful and effective design of experiment technique.

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