



Machining Parameter Setting For Facing EN8 Steel with TNMG Insert

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Abstract: Surface roughness is used to determine and evaluate the quality of a final product in faced parts. In order to get better surface finish, the proper setting of cutting parameters is crucial before the process takes place. EN8 is one whose surface hardness is high and it is used for making gudgeon pins, gears etc., is taken as work material for experimental works. This paper describes the Taguchi method based robust design philosophy for minimization of surface roughness in facing. Three parameters namely cutting speed, feed and depth of cut were identified and investigated at three levels to study the effect of parameters on surface roughness. Experimental works were conducted on EN8 material using CNC Lathe based on L_9 orthogonal array. Based on the signal to noise ratio analysis, the optimal settings of the process parameters have been determined. Confirmation tests also been performed to predict and verify the adequacy of the additive models for determining the optimal surface roughness.

Keywords: EN8, Machining, Facing, Surface roughness, Taguchi Technique

I. INTRODUCTION

The drastic increase of consumer needs for quality metal cutting related products (more precise tolerance and better surface finish) has driven the metal cutting industry to continuously improve quality control of the metal cutting processes. The quality of surface roughness is an important requirement of many work pieces in machining operations. Within the metal cutting processes, the facing process is one of the most fundamental metal removal operations used in the manufacturing industry. Surface roughness which is used to determine and evaluate the quality of a product is one of the major quality attributes of a faced product [1].

Surface roughness of a machined product could affect several of the product's functional attributes such as contact causing surface friction, wearing, light reflection, heat transmission, ability of distributing and holding a lubricant, coating and resisting fatigue. Therefore, surface roughness is one of the important quality aspects in facing operations [2]. Diwaha et al [3] used Taguchi method for turning parameter optimization of AISI 1040 steel. Optimum cutting parameters for turning AISI 1030 carbon steel bar was identified by Nalbant et al [4].

In order to obtain better surface roughness, the proper setting of cutting parameters is crucial before the process takes place. As a starting point for determining cutting parameters, technologists could use the hands on data tables that are furnished in machining data handbooks. Previously the trail – and – error approach could be followed in order to obtain the optimal machining conditions for particular operations. Recently, a Design of Experiment (DOE) has been implemented to select manufacturing process parameters that could result in a better quality product.

A systematic approach by Taguchi method for identifying optimum surface roughness in end milling operations was used by John and Joseph [5]. In their study, three independent variables, each with three levels, had total of $(3^3) = 27$ experimental runs. Oftentimes, the optimum metal cutting process required studying more than three factors for the cutting parameters. For example, if a DOE setup considered three independent variables, each with at least three levels, then $(3^3) = 27$ runs were required in the experiments. Imagining the total cost of these experimental runs, one could conclude that it was very costly for the industry. In addition, the time of these runs could delay any quality resolving actions for the industry. More Industrial Technology graduates are facing challenges to improve the quality of products and processes with minimum cost and time constraints in their

careers. The Taguchi parameter design techniques have been proved to be successful, economical and viable in meeting this challenge ([5] - [15]). Therefore, there is a need to introduce Taguchi parameter design.

Most of the works regarding surface roughness has focused in turning, milling and drilling operations ([3] – [13]). Only a limited amount of research has been reported in the open literature dealing with facing operations ([2], [7]). As well as the research work which uses EN8 metal as a specimen is also very less. This EN8 material is used for making gudgeon pins, gears etc. where surface roughness is an important factor in facing. Hence there is a scope for studying machining parameter setting for facing EN8 steel using Taguchi Technique.

II. TAGUCHI APPROACH

Taguchi method based robust design approach has produced a unique and powerful quality improvement discipline that differs from traditional practices ([11] – [16]). Taguchi approach can economically satisfy the need of problem solving and product/process design optimization projects in the manufacturing industries. By applying this, it is possible to reduce the time for experimental investigations and improve the process quality. Robust design is a methodology for finding the optimum setting of the control factor to make the product or process insensitive to the noise factors. Robust design is based upon the technique of matrix experiments. Experimental matrices are special orthogonal arrays, which allow the simultaneous effect of several process parameters to be studied efficiently. The purpose of conducting the orthogonal experiment is to determine the optimum level for each factor and to establish the relative significance of individual factors in terms of their main effects on the response. Taguchi suggests signal to noise ratio (S/N) as the objective function for matrix experiments. The 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). Taguchi classifies objective function into three categories, such as smaller the better type, larger the better type, nominal the best type. The optimum level for the factor is the level that results in the highest value of signal to noise ratio in the experimental region [9]. The main objective of this paper is to study the different process parameters during facing of EN8 steel using robust design methodology. This paper attempts to introduce how Taguchi parameter design could be used in identifying the significant processing parameters and optimizing the surface roughness of facing operations.

III. PLANNING FOR EXPERIMENTATION

A. Selection of factors, levels and orthogonal arrays

Three operating factors, viz., depth of cut, feed and cutting speed have been selected for parametric optimization and each parameter has three levels [12]. These factors and three levels are given in Table 1. Orthogonal array gives more reliable estimates of factor effects with less number of experiments, when compared to the traditional methods, such as one factor at a time experiments. With three factors at three levels, the total degrees of freedom are 6. Hence, L_9 orthogonal array having 6 degrees of freedom was selected for the controllable factors. L_9 indicates 9 trials considered for experimentation, the array along with factor assignment to the columns is given in Table 2.

TABLE 1 FACTORS AND LEVELS

Sl.No	Factors	Units	Levels		
			1	2	3
1	Depth of Cut (DOC)	mm	0.8	1.0	1.2
2	Feed (F)	mm/rev	0.15	0.20	0.25
3	Cutting Speed (V)	m/min	200	240	280

B. Conducting the experiments and measurement of responses

Experiments were conducted on CNC Fanuc Oi-TA Horizontal Turning Centre using EN8 alloy steel rods of 30mm diameter as dictated by L_9 orthogonal array. According to the hardness of the material the TNMG 160404 EN-TF CTC 2135 inserts was selected. Soluble cutting oil emulsion in water was used as a coolant. One specimen for each trial condition was prepared. Thus nine specimens were faced and the surface roughness was

measured at three different locations in each specimen and the average value was taken. The surface roughness was measured using Mitutoyo Surf Tester 211 with a cut off length of 0.25mm. The results of the experiments for nine trial conditions are reported in Table 2.

TABLE 2 L₉ ORTHOGONAL ARRAY WITH FACTORS, RESPONSES AND S/N RATIOS

Sl. No.	DOC	F	V	Average Surface Roughness Ra (μm)	S/N Ratio
1	1	1	1	0.29	10.75
2	1	2	2	0.73	2.73
3	1	3	3	0.64	3.87
4	2	1	2	0.60	4.44
5	2	2	3	0.54	5.35
6	2	3	1	0.99	0.09
7	3	1	3	0.46	6.74
8	3	2	1	0.59	4.58
9	3	3	2	0.61	4.29

C. Analysis for optimization of operating parameters

In Taguchi method, the signal to noise ratio (S/N) analysis has been carried out to determine the optimal parametric condition of facing process. For that, smaller-the-better type category responses are considered for the present analysis ([12], [13]). The S/N ratio for smaller-the-better category is

$$\eta = -10 \log_{10} \left\{ \frac{1}{n} \sum_{i=1}^n y_i^2 \right\} \quad \dots\dots (1)$$

where, y is the response and n is the number of replications of each trial i. The S/N ratios were computed using Eq. (1) for each of the 9 trials and the values are reported in Table 2.

The data analysis procedure using Taguchi experimental framework involves Analysis of Means (ANOM) and Analysis of Variance (ANOVA). The ANOM helps in identifying the optimal factor combinations. Based on ANOM, the optimum levels for each factor resulting from matrix experiment are shown in Table 3. The ANOM table for the raw data of surface roughness is indicated in Table 4.

TABLE 3 ANOM FOR S/N RATIO

Factors	Levels			Optimum
	1	2	3	
V	5.78	3.29	5.20	5.78 (V ₁)
F	7.31	4.22	2.75	7.31 (F ₁)
DOC	5.14	3.82	5.32	5.32 (DOC ₃)

TABLE 4 ANOM FOR RAW DATA

Factors	Levels			Optimum
	1	2	3	
V	0.55	0.71	0.57	0.55 (V ₁)
F	0.45	0.62	0.74	0.45 (F ₁)
DOC	0.62	0.64	0.54	0.54 (DOC ₃)

FIGURE 1 S/N RESPONSE GRAPH FOR MACHINING PARAMETERS

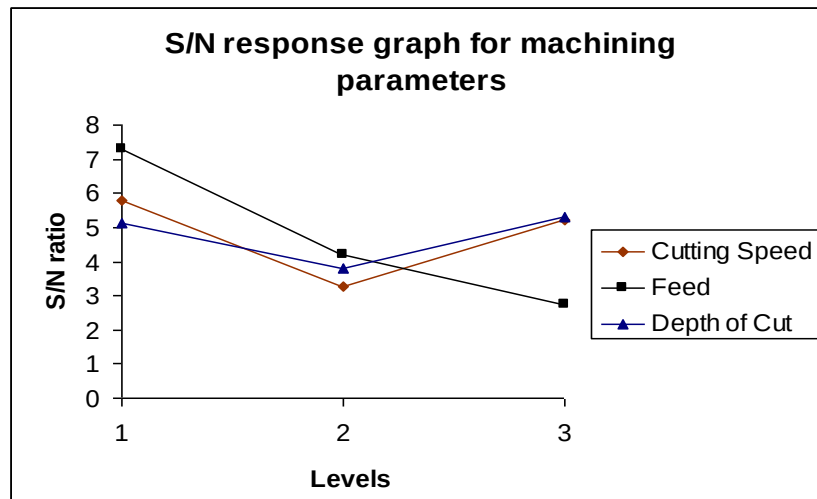
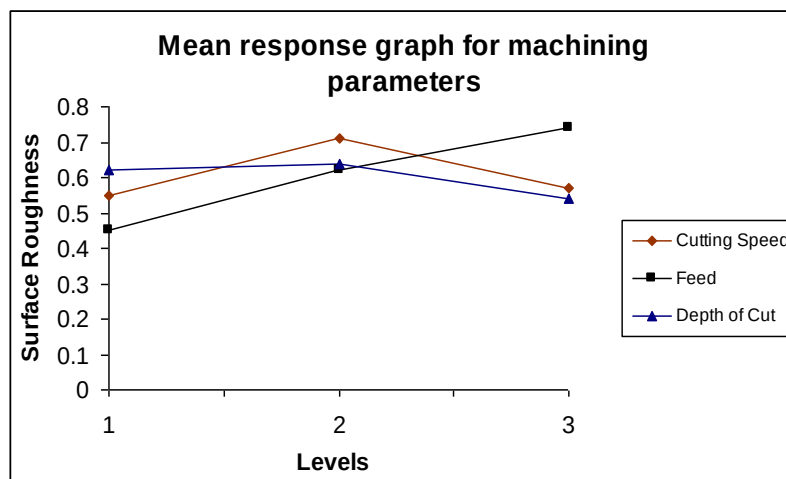


FIGURE 2 MEAN RESPONSE GRAPH FOR MACHINING PARAMETERS



From table 3 and 4 and Figure 1 and 2, it is observed that lower level of cutting speed and feed and higher level of depth of cut gives the optimum cutting parameters for facing EN8 steel with TNMG inserts (i.e) Cutting speed (V_1) = 200m/min, Feed (F_1) = 0.15mm/m and Depth of cut (DOC_3) = 1.2mm

ANOVA establishes the relative significance of factors in terms of their percentage contribution to the response. ANOVA is needed for estimating the error variance for the effects and variance of the prediction error. In Table 5, the ANOVA for S/N ratio are shown and in Table 6, the ANOVA for raw data of surface roughness are indicated. It is clear from ANOVA for raw data that feed influences 45.50 % of the surface roughness, cutting speed contributes 16.55 % of the surface roughness and depth of cut influences 5.56 % of the surface roughness.

TABLE 5 ANOVA FOR S/N RATIO

Factors	DoF	Sum of squares	Mean squares	% Contribution
V	2	10.19	5.09	15.16
F	2	32.49	16.24	48.33
DOC	2	4.03	2.01	5.99
Error	2	20.52	10.26	30.52
Total	8	67.23	8.40	100.00

TABLE ANOVA FOR RAW DATA

Factors	DoF	Sum of squares	Mean squares	% Contribution
V	2	0.048	0.024	16.55
F	2	0.132	0.066	45.5
DOC	2	0.016	0.007	5.56
Error	2	0.095	0.048	32.39
Total	8	0.290	0.036	100.00

D. Determination of optimal surface roughness

The optimal surface roughness is predicted at the selected optimal setting of process parameters. The significant parameters with optimal levels are already selected as: V_1 , F_1 , and DOC_3 .

The estimated mean of the response characteristic can be computed as:

$$\mu_{Ra} = V_1 + F_1 + DOC_3 - 2 * T_{Ra} \quad \dots\dots (2)$$

where T_{Ra} = overall mean of surface roughness. V_1 , F_1 , and DOC_3 are the mean values of the surface roughness with parameters at optimum levels.

Hence the predicted optimum value for S/N ratio is $\mu_{S/N} = 8.876$ and the predicted optimum value for the raw data is $\mu_{Ra} = 0.3381$.

A confidence interval for the predicted optimum S/N ratio on a confirmation run can be calculated using the following equation:

$$C.I. = \sqrt{F_{\alpha}(1, f_e) V_e \left[\frac{1}{n_{eff}} + \frac{1}{R} \right]} \quad \dots\dots (3)$$

Where, $F_{\alpha}(1, f_e)$ is the F – ratio required for α , α is the risk, f_e is the error DOF, V_e is the error variance, n_{eff} is the effective number of replications and is equal to

$$n_{eff} = \frac{N}{1 + \text{Total DOF}} \quad \dots\dots (4),$$

R is the number of repetitions for confirmation experiment and N is the total number of experiments ([7], [10]).

Using the values of S/N ratios $V_e = 10.26$ and $f_e = 2$ from Table 5, the C.I. was calculated.

Total DOF associated with the mean (μ_{Ra}) = $2 * 3 = 6$.

Total trials = 9; $N = 1 * 9 = 9$; $n_{eff} = 9 / (1+6) = 1.286$.

$\alpha = 0.05$.

$F_{0.05}(1,2) = 18.5$ (tabulated).

The calculated C.I. for S/N ratio = ± 18.37 .

The predicted mean of the S/N ratio is $8.876\mu m$.

The 95 % confidence interval of the predicted optimum S/N ratio is:

$$(\mu_{Ra} - C.I.) < \mu_{Ra} (N) < (\mu_{Ra} + C.I.)$$

$$-9.49 < \mu_{S/N} < 27.246$$

For optimum surface roughness:

$$-0.912 < \mu_{Ra} < 1.588$$

3.5 Confirmation Experiments

Verification experiments were conducted to check, how close the optimum conditions suggested by the manual experiment was related with the real ones. It was conducted at the optimal setting of facing process parameters recommended by the investigation. The mean value of surface roughness was found to be $0.28\mu m$. The difference between the predicted optimum surface roughness value by Taguchi method and the verification experiment value is low. This result was within C.I. of the predicted optimal surface roughness.

IV. CONCLUSION

Taguchi method is used and is a powerful tool for optimization, which provides a systematic and effective methodology for the design optimization of cutting parameters. The percentage contributions of parameters in affecting variation in surface roughness while machining EN8 steel with TNMG 160404 EN-TF CTC 2135 insert are: The feed has greater influence on the surface roughness followed by the cutting speed. From the analysis it is

revealed that the feed, cutting speed and depth of cut are prominent factors which affect the facing operations. Confirmation test results proved that the determined optimal combination of machining parameters satisfy the real requirements of machining operations in the facing of EN8 materials.

5. REFERENCES

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