Optimize the Surface Roughness During Machining of EN-8D Steel Using Taguchi Approach

[1]Subeg Singh, [2]Sanjeev Kumar, [3]Sunil Kumar
[1,2,3]Dept. of Mechanical Engineering, BCET Gurdaspur, Punjab, India

Abstract
The requirements of high surface quality of the finished product are the main aim of manufacturing industries. Surface quality of the finished product is affected by several factors like cutting parameters, tool geometry, work piece hardness and environmental conditions. Attempt is to be made for optimize the surface roughness of EN-8D work material using different cutting parameters and insert shapes. The results indicate that cutting speed was found out to be the dominant factor on the surface roughness followed by feed rate.

Keywords
Design of Experiment, Surface Roughness, ANOVA, S/N Ratio

I. Introduction
The challenge of modern machining industries mainly focused on the achievement of high quality in terms of work part dimensional accuracy and surface finish, high production rate and cost saving. Surface finish is related to the end product and also allows the proper function of the product in the application. The resultant surface roughness in the cutting operation is determined by ideal surface roughness (geometry of the tool and machining parameter) and natural surface roughness (due to irregularities and uncontrollable factors in the cutting operation) [1]. During machining operation surface, roughness is also influenced by work material factors, geometric factors and machine tool factors [2]. The better surface quality is achieved by machining EN-8D steels at low feed rate and high spindle speed [3]. It was investigated that the feed has the variable effect on surface roughness [4]. For the surface roughness, the feed rate is the main influencing factor, followed by the tool nose radius and cutting speed. Depths of cut have no significant effect on the surface roughness [5]. Also, the surface quality is improved when the cutting speed increased [6]. Also like feed rate, the cutting speed has a main influence on the surface roughness. Higher the cutting the speed lower the value of surface roughness [7]. Hence several researchers have done the research on machining, and it was found that surface quality is the desired output during the machining.

II. Experimental Details

A. Work Materials
For the present study EN-8D steel was selected as work material. The materials used as wide range of applications e.g., It is used to manufacture axle's, rams and ring gears, conveyor parts, logging parts, spindles, shafts, sprockets, studs, pinions pump shafts, etc. Work pieces of length 300mm and 50mm were used in experimentation. The workpiece material was hardened to 25-30 HRC before machining. The chemical composition of work piece material has been shown in table (1) given below.

Table 1: Composition of Material EN-8D.

C%	Si%	Mn%	P%	Cr%	S%
0.40/0.45	0.15/0.35	0.70/0.90	0.035max	0.20max	0.035max

B. Cutting Inserts:
As per the problem formulated, the surface roughness was investigated for the different shapes of carbide inserts. The tungsten carbide cutting inserts were selected for the experimentation. The inserts were triangular and square in shape. The cutting inserts were purchased from the Sandvik company ltd.

C. Machine Tool:
Machine that holds the workpiece between two rigid and strong supports, called centres. The chuck is mounted on the projected end of the machine spindle. The cutting tool is rigidly held and supported in the tool post and is fed against the revolving work. There were many types of machine tools were available in the market but the required machine tool, which was used in the present study was made of HMT limited. The lathe machine of LB-17 model was used.

Fig. 1: Experimental Setup

III. Experimental Design:
Taguchi approach is used to design an experiment (DOE). It is well- known technique that provides process optimization used for high quality system. It provides optimum condition of process parameter that is least sensitive to the various causes of variations. Signal to noise ratio and orthogonal array are two major tools used in robust design. The S/N ratio characteristics can be divided into three categories (a) Nominal the best (b) Smaller the better (c) Larger is better features. For the surface roughness, the solution is "smaller is better" and S/N ratio is determined according to the following equation:

$S/N = -10 \, Log_{10}$ [mean of sum of squares of measured data]
Where, S/N = Signal to Noise Ratio, n = No. of Measurements, y = Measured Value.
Selection of parameters and their levels must be taken into consideration before finalizing the design of experiments [8]. In the present's research three different cutting parameters spindle speed, feed and depth of cut having four different levels of each parameter are used as shown in table (2). Also, two different types of inserts are used during experimentation. Therefore, total four parameters are considered in the experiment. Degree of freedom

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(DOF) for cutting parameters (speed, feed and depth of cut) is 3 each and 1 DOF for cutting inserts. Total DOF in the present investigation are:

(1 × 1) + (4 × 3) = 13.

Hence L16 orthogonal array can be used for planning the experimentation, based on the computation of the degree of freedom as shown in table (3). Where cutting speed selected as 50, 75, 100, 125 m/min feed rate are 0.1, 0.2, 0.3, 0.4 mm/rev and depth of cut as 0.5, 1.0, 1.5, 2.0mm have been taken in the experiment. Also, two shapes, triangular and square insert have been taken.

Table 2: Input Machining Parameters at Different Levels

Input machining parameter	Levels and corresponding values of machining parameters			
	Level 1	Level 2	Level 3	Level 4
Speed (mm/min)	50	75	100	125
Feed (mm/rev.)	0.1	0.2	0.3	0.4
Depth of cut (mm)	0.5	1.0	1.5	2.0
Insert form	Triangular	Square	……	……

All these calculation are performed using software Minitab-14.

Table 3: Mixed Design L16 Array

Speed (mm/min)	Feed (mm/rev.)	Depth of cut (mm)	Insert shape
50	0.1	0.5	Triangular
50	0.2	1	Triangular
50	0.3	1.5	Square
50	0.4	2	Square
75	0.1	1	Square
75	0.2	0.5	Square
75	0.3	2	Triangular
75	0.4	1.5	Triangular
100	0.1	1.5	Triangular
100	0.2	2	Triangular
100	0.3	0.5	Square
100	0.4	1	Square
125	0.1	2	Square
125	0.2	1.5	Square
125	0.3	1	Triangular
125	0.4	0.5	Triangular

The main effect plot of different process parameters (cutting speed, feed depth of cut and tool geometry) on surface roughness are calculated and plotted as shown in fig. 2.

The average value of S/N ratios has been calculated to find out the effects of different parameters and as well as their levels. Both ANOVA technique and S/N ratio are used to analyze the results and to reach on the best solution. The Table 5 indicate the response for S/N ratio in which rank show the relative importance of each factor to the response.

IV. Results and Discussion

Therefore, base upon the different setting of various parameters provided by the design of experiments as in Table 3. The experiments are performed, and the surface roughness is measured. At least three run with the same setting of parameters was taken into consideration and the mean SN ratio as shown in the Table (4).

Table 4: Output Data for Surface Roughness and SN Ratio

Speed (mm/min)	Feed (mm/rev.)	Depth of cut (mm)	Insert shape	Ra (μm) Run-1	Ra (μm) Run-2	Ra (μm) Run-3	SN Ratio
50	0.1	0.5	Triangular	3.3	3.22	3.19	-7.0764
50	0.2	1	Triangular	4.61	4.12	4.65	-10.4815
50	0.3	1.5	Square	2.54	2.36	2.14	-3.5051
50	0.4	2	Square	2.03	1.96	1.99	-6.0642
75	0.1	1	Square	3.79	3.65	3.89	-11.2743
75	0.2	0.5	Square	5.23	5.2	5.24	-12.4243
75	0.3	2	Triangular	5.38	5.21	5.48	-12.7967
75	0.4	1.5	Triangular	4.86	4.75	4.65	-11.0471
100	0.1	1.5	Triangular	3.87	3.84	3.52	-8.5428
100	0.2	2	Triangular	4.12	4.11	4.23	-9.9209
100	0.3	0.5	Square	5.69	5.12	5.95	-11.0324
100	0.4	1	Square	3.04	3.12	3.16	-10.025
125	0.1	2	Square	4.25	4.23	4.1	-12.4036
125	0.2	1.5	Square	4.11	4.03	4.15	-10.9824
125	0.3	1	Triangular	3.52	3.26	3.86	-12.4584
125	0.4	0.5	Triangular	5.23	5.24	5.36	-10.4787

The ranks and the delta values for various parameters show that Speed has the greatest effect on surface roughness and is followed by depth of cut feed and inserts form. As surface roughness is lower the better type quality characteristic. It is clear that the second level of cutting speed (A2), second level of depth of cut (B2), second level of feed (C2) and first level of inserts form (D1) result in the minimum value of surface roughness.

Table 5: Response table of Signal to Noise Ratios for Surface Roughness

Level	Speed(mm/min)	Feed(mm/rev.)	Depth(mm)	Insert shape
1	-6.782	-9.824	-10.253	-10.350
2	-11.886	-10.952	-11.060	-9.714
3	-9.880	-9.948	-8.519	
4	-11.581	-9.404	-10.296	
Delta	5.104	1.549	2.540	0.636
Rank	1	3	2	4

Analysis of variance (ANOVA) was performed at 95% confident level to identify the significant of each cutting parameters from Table 6. It is clear that the cutting speed has a significant effect on surface roughness. The contribution of another parameter feed, depth of cut and inserts form having less effect. Also, it is clear from ANOVA Table 6 the contribution by the error associated are 12.86. The terms R-Sq = 87.1% indicates that the model is best and it cover all the variation provided by different process parameters.

Table 6: ANOVA for SN Ratio

Source	DF	Seq SS	Adj SS	Adj MS	F	P	%contribution
Speed	3	65.686	65.686	21.895	8.59	0.020	66.30
Feed	3	5.167	5.167	1.722	0.68	0.603	5.21
Depth of cut	3	13.852	13.852	4.617	1.81	0.262	13.98
Insert shape	1	1.620	1.620	1.620	0.64	0.461	1.63
Residual Error	5	12.742	12.742	2.548			12.86
Total	15	99.067					

S = 1.596 R-Sq = 87.1% R-Sq(adj) = 61.4%

The main effect plot was constructed by using Taguchi orthogonal array technique with the help of Minitab software 14. The signal to noise ratio was found by considering smaller the better qualities features for surface roughness. The plot between data means and mean of the signal to noise ratio as shown in fig. 2.

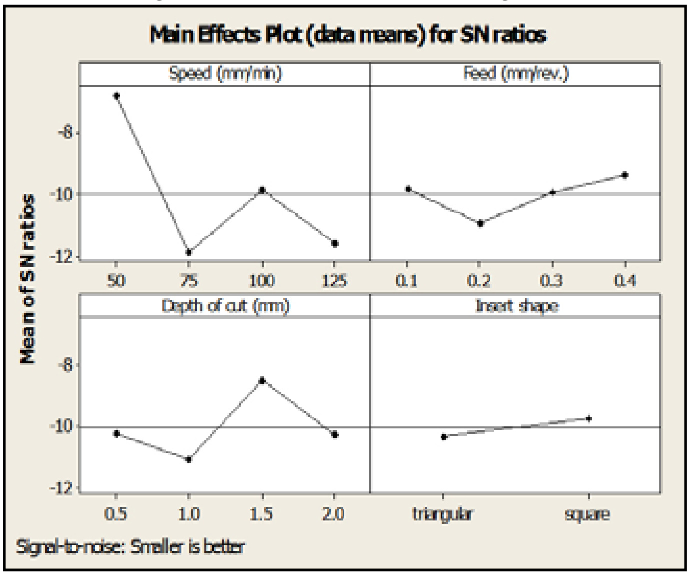

Fig. 2: Main Effect Plot for Surface Roughness

From the fig. 2 the optimum parameters found are cutting speed 75 m/min, feed 0.2 mm/rev, depth of cut 1.0 mm and triangular insert shape. The minimum surface roughness for optimum parameter is recorded on these levels.

V. Conformation Test:

In order to validate the results, confirmation experiments were conducted for response characteristic (surface roughness) at optimal levels of the process variables. The average values of the features were obtained and compared with the predicted values It is to be pointed out that these optimal values are within the specified range of process variables

Table 7:

Surface roughness at optimum level	Experimental value mean	Predicated value	% error
A2B2C2D1	5.12	6.24813	8.591

VI. Conclusion

The ANOVA for the mean SN ratio shows that cutting speed as significantly affects the surface roughness and its contribution is 66.30 %.

The minimum surface roughness is obtained at cutting speed 75 m/min, feed 0.2 mm/rev, depth of cut 1.0 mm and triangular insert shape.

The results obtained from conformation test shows that the error in experimental and predicted values is 8.591 % which is less than 10 %. It shows that our experimental results are fit to the best.

The effect of inserts shape on surface roughness is minimum at low cutting speed.

VII. Scope of Future Work:

1. Surface qua;ity can also be measured by varying the other geometrical parameters as (tool nose radius, rake angle, side cutting edge angle etc.).
2. Surface quality can also check by using other shape of inserts.
3. Surface quality can also be measured by using chip breakers and wipers inserts.
4. Surface quality can also be measured under different environmental like flood lubricants; Minimum quantity of cutting fluids, solid lubricants and gaseous lubricants .
5. Surface quality during hard turning can also be checked.
6. Mathematical modelling can be made.

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Subeg Singh is a student of M.Tech Production Engineering, BCET Gurdaspur, Punjab, India.

Sanjeev Kumar is a Faculty Mechanical Engineering Department BCET Gurdaspur, Punjab, India.

Sunil Kumar is a Faculty Mechanical Engineering Department BCET Gurdaspur, Punjab, India.