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Taguchi *b*ased optimization of machining parameters for surface roughness in CNC turning of EN19 and EN31 steel

Venkatesh B, Udhay S Yargambalimath, Vishwas C J
Dept. of Mechanical Engineering
Mangalore Institute of Technology & Engg
Moodabidri
India
cjvthermal@gmail.com

Gajanan M Naik, Sachin B
Dept. of Mechanical Engineering
National Institute of Technology
Suratkal
India
gajamnaik@gmail.com

Abstract-In this work, the machining parameters are optimized in turning based on Taguchi method. The experiments have been carried out in dry condition using L9 orthogonal array. The machining parameters are selected for operations are spindle speed, feed rate and depth of cut with each three levels in CNC turning of EN19 and EN31 steel. As a result Feed rate was found to be dominantly affecting the surface roughness for both materials. This paper also estimates the contribution and significance of process parameters through analysis of variance (ANOVA) technique. The optimal setting parameters of surface roughness for EN-19 and EN-31 is A3-B1-C3 (1200rpm, 0.25mm/rev-0.6mm) and A2-B1-C2 (800rpm, 0.25mm/rev-0.4mm) respectively.

Keywords-Ra, CNC Turning, ANOVA, EN-19, EN-31.

1. INTRODUCTION

Metal cutting is one of the vital processes and widely used manufacturing processes in engineering industries. Highly competitive market requires high quality products at minimum cost. Products are manufactured by the transformation of raw materials [1]. Industries in which the cost of raw material is a big percentage of the cost of finished goods, higher productivity can be achieved through proper selection and use of the materials. To improve productivity with good quality of the machined parts is the main challenges of metal industry; there has been more concern about monitoring all aspects of the machining process. Surface finish is an important parameter in manufacturing engineering and it can influence the performance of mechanical parts and the production costs [2]. The ratio of costs and quality of products in each production phase has to be monitored and quick corrective actions have to be taken in case of deviation from desired output. Surface properties such as roughness are critical to the functional ability of machine components. Increased understanding of the surface generation mechanisms can be used to optimize machining process and to improve functional ability of the component. D. ManivelR. Gandhinathan [3] have studied the Optimization of surface roughness and tool wear in hard turning of austempered ductile iron using Taguchi method the study revealed that the main contributing factors affecting the surface roughness and tool wear were cutting speed with a contribution of 49.1% and 50.2% respectively.Patole P. B.a , Kulkarni V. V. [4] worked on Optimization of Process Parameters based on Surface Roughness and Cutting Force in MQL Turning of AISI 4340 using Nano Fluid which resulted optimal parameters are as lowest feed rate, cutting speed and depth of cut. Diptikanta Das et al. [6] have investigated Optimization of machining parameters and development of surface roughness models during turning Al-based metal matrix composite. The analysis resulted Rz and Ra reduced with increase in lathe spindle speed, but increased with increasing either feed or depth of cut. Numerous investigators have been conducted to determine the effect of parameters such as feed rate, tool nose radius, cutting speed and depth of cut on surface roughness in hard turning operation. The surface roughness decreases with increasing nose radius. Large nose radius tools have produced better surface finish than small nose radius tools. Based on the literature review it was found that the factors that highly influence the process efficiency and output characteristics are spindle speed, feed rate, depth of cut and cutting environment. Experimental works have been carried out on the above mentioned parameters for EN19 and EN31 steels.

2. EXPERIMENTATION

Based on the properties and their application in the manufacturing industry the EN-19 and EN-31 steel materialsof 20mm diameter and 150mm length rolled rod is used for this research work and the machining has been carried out with ACE-CNC Turning experimental setup under dry condition. The tool used for the process is carbide tip tool, the CNC turning setup and turned components of EN-19 and EN-31have been shown in Fig.1. For this study L9 OA experiments were used.

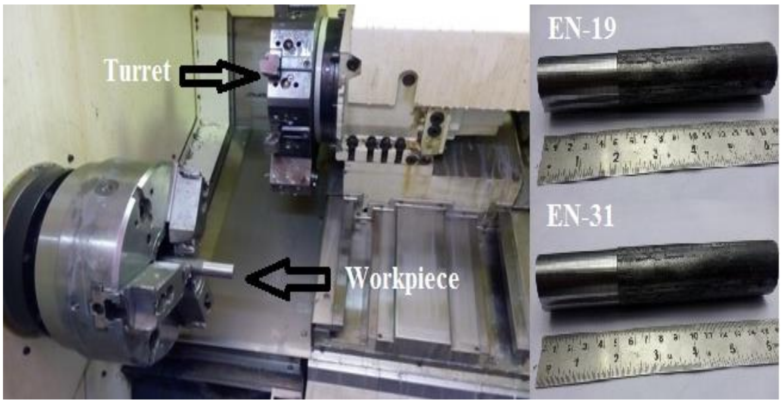

Fig 1. Experimental setup and machined component

A. Design of Experiments:

In full factorial design several experiments to be carried out which consumes execution time. In order to overcome this problem Taguchi method is employed to reduce the experiments. This study gives an attention to three control parameters, and each parameters have three levels which are shown in Table 1.Therefore, an L9 (3^4) orthogonal array (OA) experimental design was used. Table 2 presents L9 experiments with response [8-10].

Table 1: Control Parameters and their levels

Parameter	Factor	Level 1	Level 2	Level 3
Spindle speed(rpm)	A	400	800	1200
Feed rate (mm/rev)	B	0.25	0.50	0.75
Depth of cut(mm)	C	0.2	0.4	0.6

Table2: L9 Orthogonal design and response parameters

Sl No	Rotational Speed (rpm)	Feed rate (mm/rev)	Depth of Cut(mm)	Ra(µm)	
				EN-19	EN-31
1	400	0.25	0.2	10.2	1.12
2	400	0.50	0.4	12.56	6.36
3	400	0.75	0.6	8.96	10.86
4	800	0.25	0.4	4.56	2.41
5	800	0.50	0.6	8.09	5.63
6	800	0.75	0.2	14.6	10.16
7	1200	0.25	0.6	4.77	6.33

8	1200	0.50	0.2	9.28	7.11
9	1200	0.75	0.4	9.22	9.18

3. RESULTS AND DISCUSSION

A. Optimization of Machining Parametersof EN 19 Steel.

The main effect plots for surface roughness of EN-19 steel have been shown in Fig 2.From the Fig 2 it was observed that spindle speed and depth of cut has inverse effect and feed rate has direct effect on surface roughness, which means by increasing rotational speed and depth of cut the surface roughness decreases and also by increasing feed rate increases the surface roughness. Further, from the mean plot A3-B1-C3 (1200rpm, 0.25mm/rev-0.6mm) is considered as optimal process parameters for getting minimum surface roughness.

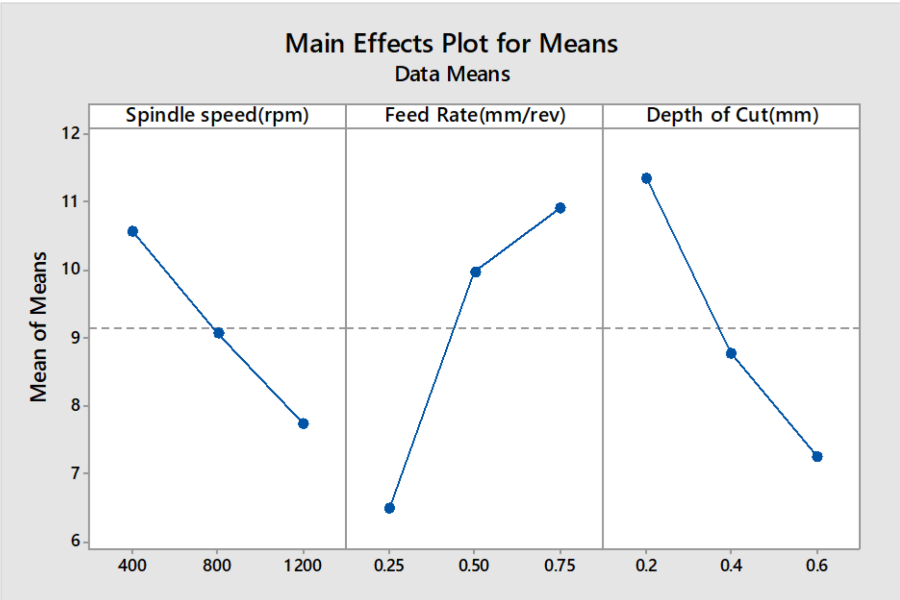

Fig. 2 EN-19 Main effects plot for surface roughness

B. Optimization of Machining Parameter of EN-31 Steel.

The main effect plots of surface roughness for EN-31 steel have been shown in Fig 3. From the Fig 3 it was observed that rotational speed feed rate and depth of cut has direct effect on material removal rate, which means by increasing rotational speed feed rate and depth of cut the surface roughness increases and also from the plot A2-B1-C2 (800rpm, 0.25mm/rev-0.4mm) is noted optimal process parameters for getting minimum surface roughness.

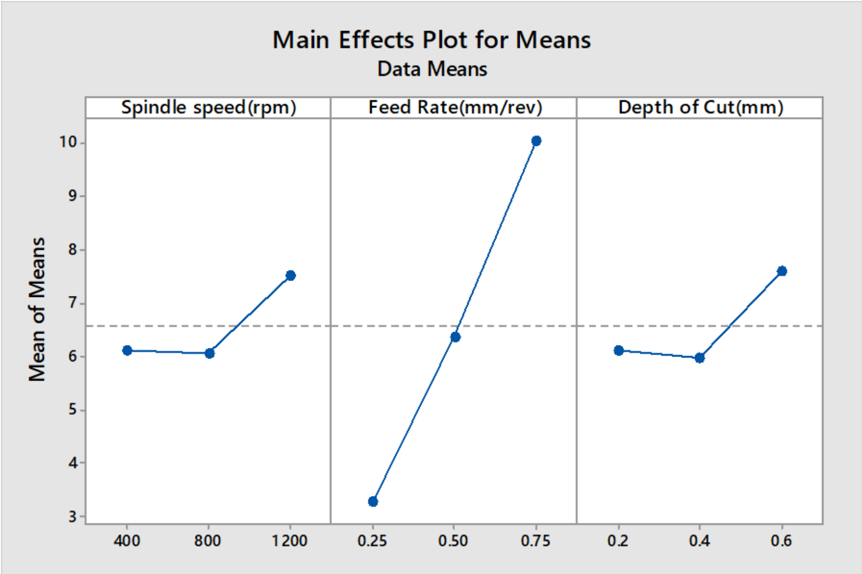

Fig. 3 EN-31 Main effects plot for surface roughness

C. Analysis of Variance (ANOVA):

The analysis of variance estimates the significance of machining parameters on surface roughness. The significance of process parameters are identified by comparing α=0.05 level of 95% confidence level with p-value column, if p-value is less than 0.05 then the process parameter is said to be significant and p value is more than 0.05, then the process parameters is said to be insignificant and also ANOVA table gives the influencing parameters on response [5, 7].

The analysis of variance presents the significance of process parameter on response variable for EN-19 material, From Table 3 it is conclude that rotational speed,feed rate and depth of cuthas shown insignificant effect on surface roughness, also from the F- test value can conclude that feed rate is most influencing parameters followed by depth of cut and rotational speed.

Table 3: Analysis of variance of surface roughness for EN-19 steel

Source	DF	Adj SS	Adj MS	F-Value	P-Value	Remark
Rotational speed	2	11.91	5.957	0.86	0.538	Insignificant
Feed Rate	2	32.43	16.214	2.33	0.300	Insignificant
Depth of cut	2	25.63	12.814	1.84	0.350	Insignificant
Error	2	13.90	6.949	-	-	-
Total	8	83.87	-	-	-	-

The analysis of variance for EN-31 steel materials are presents the significance of process parameter on response variable, From Table 4 it can be seen that none of the parameter significant on surface roughness, also from the F- test value can conclude that feed rate is most influencing parameters followed by depth of cut and rotational speed.

Table 4: Analysis of variance of surface roughness for EN-31 steel

Source	DF	Adj SS	Adj MS	F-Value	P-Value	Remark
Rotational speed	2	4.208	2.104	0.51	0.661	Insignificant
Feed Rate	2	68.145	34.572	8.43	0.106	Insignificant
Depth of cut	2	4.837	2.419	0.59	0.629	Insignificant
Error	2	8.199	4.099	-	-	-
Total	8	86.389	-	-	-	-

D. Regression Model

The regression models to predict the theoretical surface roughness have derived from the experimental data by using MINITAB 17 software.The theoreticalsurface roughness equations for EN-19 and EN-31 steel materials are given below.

Surface roughness (µm) for EN19 = 11.62 - 0.00352 Spindle speed (rpm) + 8.83 Feed Rate (mm/rev)- 10.22 Depth of Cut(mm)
Surface roughness (µm) for EN31 = -3.11 + 0.00178 Spindle speed(rpm) + 13.56 Feed Rate (mm/rev)+ 3.69 Depth of Cut(mm)

4. Confirmation Test

The Taguchi's L9 type orthogonal array experiments have been carried out on EN19 and EN 31 steel by considering the spindle speed, feed rate and depth of cut as input parameters, surface roughness as output response. From the analysis optimal process parameters have been identified to minimize surface roughness. The optimum setting parameters of CNC turning and confirmation test results of Ra presents in Table 5. From the results it is conclude that the surface roughness is lower in EN-31 steel compare to EN-19 steel shown in Fig 5, also the Fig 4 have been shown the Ra versus machining parameters for EN-19 and EN-31 steel.

Table 5: Confirmation test results

	Surface roughness (µm)	
	EN-19	EN-31
Optimal setting	A3-B1-C3	A2-B1-C2
Predicted Value	3.47	3.18
Experimental Value	**3.23**	**2.19**
Remark	High	Low

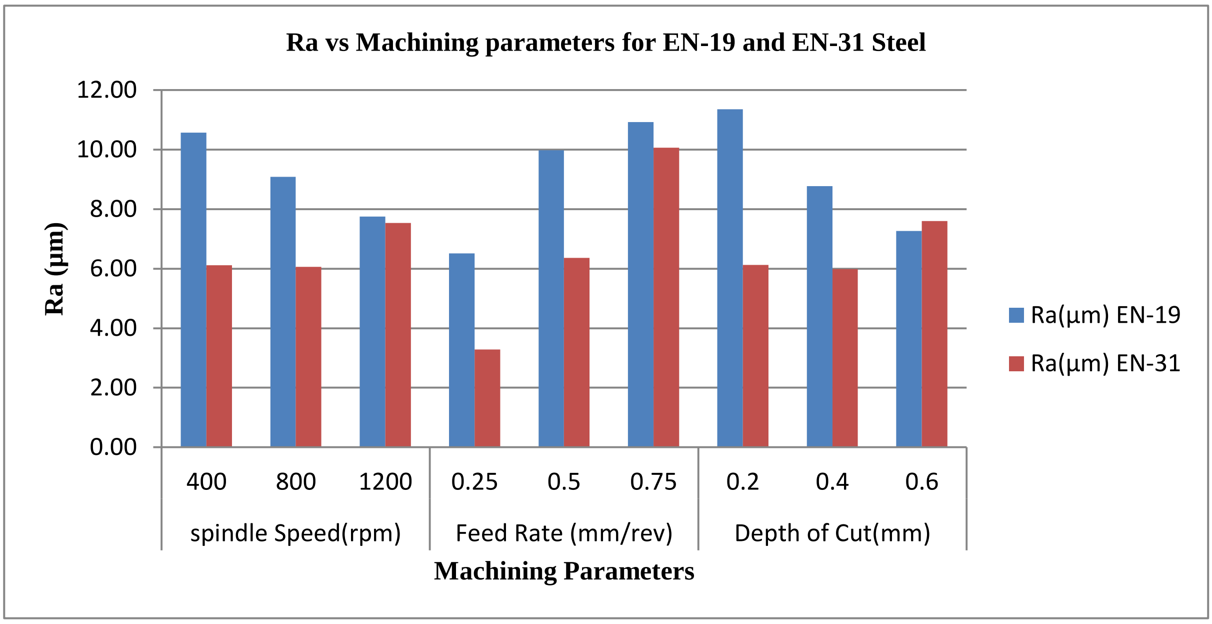

Fig 4 Comparison of surface roughness for EN-19 and EN-31 steel

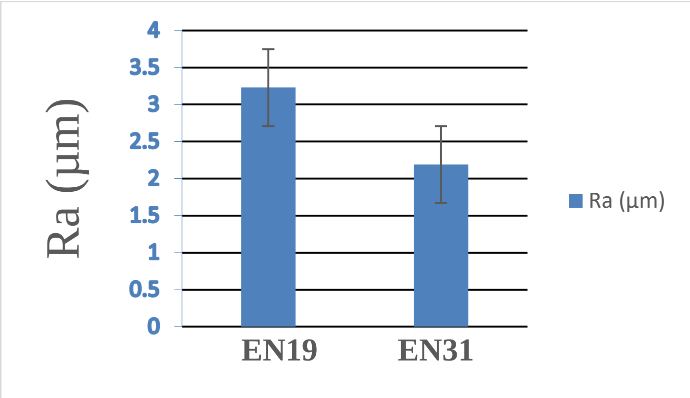

Fig 5 Experimental Ra for EN-19 and EN-31 steel

5. CONCLUSION

The CNC turning investigation on surface roughness has been carried out for EN-19 and EN-31 steel , in this research work the effect of spindle speed, feed rate and depth of cut on response have been studied through L9 Taguchi's orthogonal array and significance of process parameters are analyzed through ANOVA. The following important conclusions were drawn.

1. The surface roughness increases with increase in feed rate for both EN-19 and EN-31 materials.
2. The optimal setting parameters of surface roughness for EN-19 and EN-31 is A3-B1-C3 (1200rpm, 0.25mm/rev-0.6mm) and A2-B1-C2 (800rpm, 0.25mm/rev-0.4mm) respectively.
3. Feed rate is most influencing parameters followed by depth of cut and rotational speed on surface roughness for both the materials.
4. EN-31 steel has shown lower surface roughness compared to EN-19 steel.

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