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THE EFFECT OF TURNING PARAMETERS ON THE RESPONSES

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ABSTRACT

The present work is to explore the effect of cutting parameters on the material removal rate and surface roughness while turning of EN19 steel using tungsten carbide insert. For the experiments, cutting speed, feed and depth of cut were considered as input parameters at three different levels. The experiments are conducted as per the taguchi's standard L9 Orthogonal array. From the taguchi results, the optimal combination of cutting parameters for material removal rate is found at: v3-f3-d3. The optimal combination of cutting parameters for surface roughness is found at v3-f1-d1. The ANOVA results showed that, the cutting speed and the feed are the most dominant factors in effecting the material removal rate and surface roughness respectively.

KEYWORDS: Material removal rate (MRR), Surface Roughness (Ra), Taguchi and ANOVA.

I. INTRODUCTION

Achieving a high material removal rate and good surface finish are the difficulties that the manufacturing companies are facing. The Material removal rate is depends on the cutting parameters but surface roughness depends on the tool geometry and material properties also. To achieve both the quality characteristics in any machining process it is customary to design the cutting parameters effectively. In actual practice designing of cutting parameters includes many factors to avoid this difficulty taguchi has proposed a design called orthogonal array. The advantage of Taguchi method is to save the effort in performing experiments, experimentation time and also to reduce the cost. To obtain optimum process parameters Taguchi suggested signal to noise (S/N) ratio, this ratio considers both the mean and variance. Taguchi has proposed three performance characteristics; they are Larger-the-better, lower-the-better and nominal-the-better. In the present work larger the better and lower the better characteristics were used for Material Removal Rate and Surface Roughness respectively. Larger-the-better: S/N ratio = -10 log [$1/ MRR^2$] Lower-the-better: S/N ratio = -10 log [R_a^2]. In the present work, EN19 medium carbon steel was turned on CNC lathe with PVD coated carbide tool. EN19 is a medium carbon steel, which has high industrial applications such as in tool, oil and gas industries. It is used for axial shafts, propeller shafts, crank shafts, high tensile bolts and studs, connecting rods, riffle barrels and gears manufacturing etc.

II. EXPERIMENTAL SETUP

For the experiments, the medium carbon steel EN19 has been chosen having dimensions of 25 mm in diameter and 75 mm of length. The chemical composition and the mechanical properties of the EN19 steel are given in the tables 1 and 2

Table 1. Chemical composition

Element	C	Si	Mn	Cr	Mo	S	P
Weight %	0.36-0.44	0.1-0.35	0.70-1	0.9-1.20	0.25-0.35	0.035 max	0.040 max

Table 2. Mechanical properties

Property	Density (g/cm3)	Tensile strength (N/mm2)	Yield strength (N/mm2)	Elongation (%)	Izod (J)	Hardness (BHN)
value	7.7	850-1000	680	13	50	248-302

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Selection of orthogonal array

In the present work three process parameters of cutting speed, feed and depth of cut are considered as the input parameters at three different levels. Taguchi's standard L9 OA has been selected for the three parameters and three levels. The work specimens are machined on CNC turret lathe (DX-200, SEIMENS make Input power: 20KW, Spindle speed: 50-3500 rpm). The selected cutting parameters with their levels and L9 OA are given in the tables 3 and 4.

Table 3. Cutting parameters with their levels

Cutting parameter	Level-1	Level-2	Level-3
Speed (v), m/min	100	175	250
Feed (f), mm/rev	0.1	0.15	0.2
Depth of cut (d), mm	0.4	0.6	0.8

Table 4. L9 Orthogonal array

Run No	Speed (m/min)	Feed (mm/rev)	Depth of cut (mm)
1	100	0.1	0.4
2	100	0.15	0.6
3	100	0.2	0.8
4	175	0.1	0.6
5	175	0.15	0.8
6	175	0.2	0.4
7	250	0.1	0.8
8	250	0.15	0.4
9	250	0.2	0.6

Measurement of responses

The material removal rate and surface roughness are considered as the experimental responses. The material removal rate is measured as the product of the cutting parameters as given in the equation 1. The surface roughness is measured with SJ-301 at three different places on the machined surface and the average is taken as the final value.

MRR = v*f*d in cm^3/min (1)

III. RESULTS AND DISCUSSIONS

The experimental results measured are given in the table 5. For the obtained responses of material removal rate and surface roughness values the signal to noise ratios are calculated using the higher-the-better and lower-the-better characteristics as given in the equations 2 and 3 respectively and shown in the table 6.

$MRR\ (HB) = -10 \log (1/MRR^2)$ (2)

$R_a\ (LB) = -10 \log (R^2)$ (3)

Table 5. Experimental results

Run No	Speed (m/min)	Feed (mm/rev)	Depth of cut (mm)	MRR (cm^3/min)	R_a (μm)
1	100	0.1	0.4	4	4.03
2	100	0.15	0.6	9	5.12
3	100	0.2	0.8	16	6.57
4	175	0.1	0.6	10.5	3.93
5	175	0.15	0.8	21	4.83
6	175	0.2	0.4	14	5.87
7	250	0.1	0.8	20	3.21
8	250	0.15	0.4	15	3.96
9	250	0.2	0.6	30	5.91

Table 6. S/N ratios of MRR, R_a

Run No:	MRR	R_a
1	12.0411	-12.1061
2	19.0848	-14.1853
3	24.0823	-16.3513
4	20.4237	-11.8878
5	26.4443	-13.6789
6	22.9225	-15.3727
7	26.0205	-10.1301
8	23.5218	-11.9539
9	29.5424	-15.4317

From the calculated S/N ratios of material removal rate and surface roughness, the mean S/N ratios are calculated and given in the tables 7 and 8.

Table 7. Response mean S/N ratio for MRR

Process parameter	Mean S/N ratio				Rank
	Level-1	Level-2	Level-3	Max-min	
Cutting speed (v), m/min	18.4027	23.2635	26.3615	7.9588	1
Feed (f), mm/rev	19.4951	23.0169	25.5157	6.0206	2
Depth of cut (d), mm	19.4951	23.0169	25.5157	6.0206	3

Total mean S/N ratio: 22.6759

Table 8. Response mean S/N ratio for MRR

Symbol	Process parameter	Mean S/N ratio				Rank
		Level-1	Level-2	Level-3	Max-min	
v	Cutting speed (m/min)	-14.2142	-13.6464	-12.5052	1.709	2
f	Feed (mm/rev)	-11.3746	-13.2727	-15.7185	4.3439	1
d	Depth of cut (mm)	-13.1442	-13.8349	-13.3867	0.6907	3

Total mean S/N ratio: -13.4553

From the mean tables of S/N ratios, it is observed that the cutting speed is the most influencing parameter on material removal rate and feed and depth of cut has equal influence. Similarly for surface roughness feed is the most influencing parameter and followed by speed and depth of cut respectively.

Results of main effect plots

From the main effect plots shown in the figures 1 and 2, the optimal combination of cutting parameters for material removal rate is observed at v3-f3-d3, i.e. 250 m/min, 0.2 mm/rev, 0.8 mm. Similarly for surface roughness the optimal combination is found at v3-f1-d1, 250m/min, 0.1 mm/rev and 0.4 mm.

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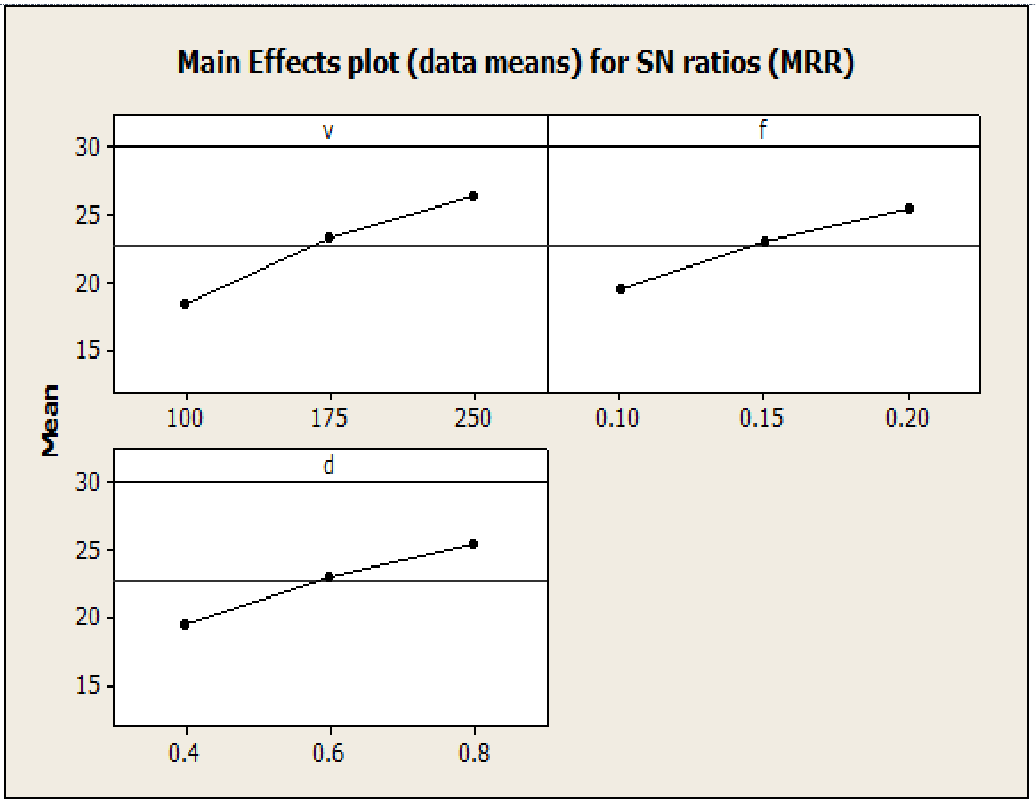

Figure 1. Main effect plot for MRR

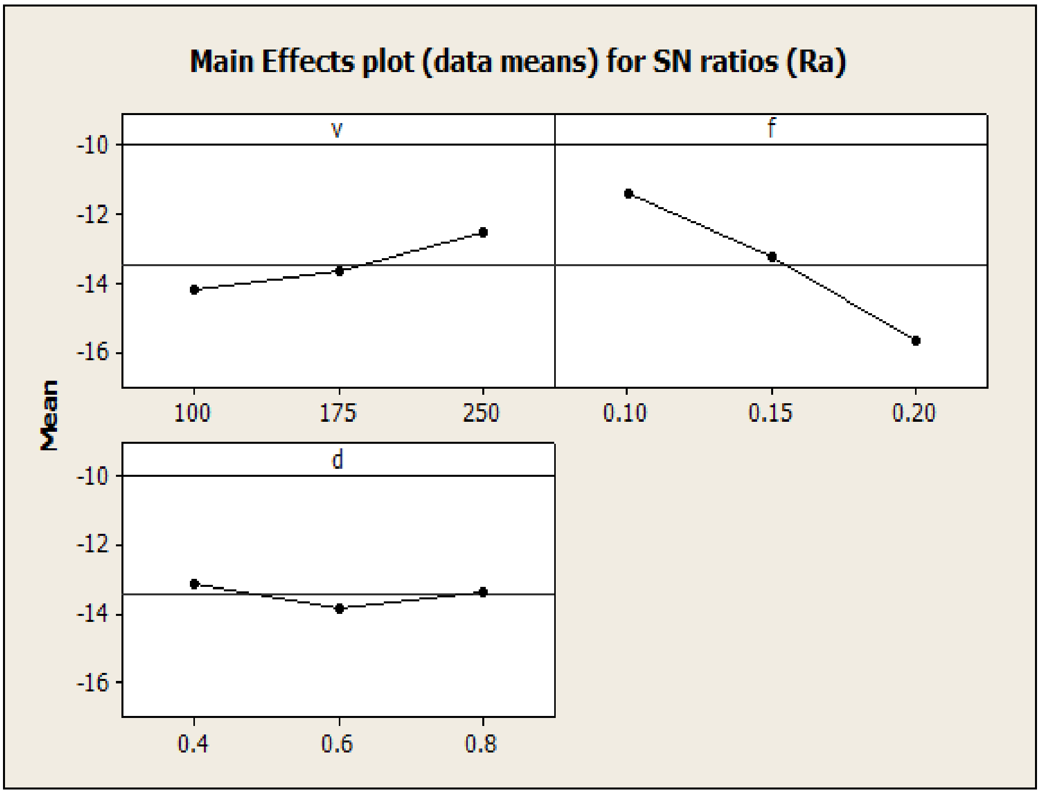

Figure 2. Main effect plot for R_a

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Regression Analysis Results

Regression analysis has been conducted to find the relationship between the cutting parameters and the responses. The regression models for the material removal rate and surface roughness are given in the equations 4 and 5.

$$MRR = -23.3 + 0.08\ v + 85\ f + 20\ d \quad (4)$$

$$R_a = 1.88 - 0.00588\ v + 24\ f + 0.63\ d \quad (5)$$

The accuracy of the models was checked with the regression analysis and the results are depicted in the tables 9 and 10. Analysis of variance (ANOVA) was also conducted to know the significance of the cutting parameters on the responses and shown in the tables 11 and 12. From the results, it is clear that the speed and feed are the most influencing parameters for material removal rate and surface roughness respectively.

Table 9. Regression analysis of MRR

Predictor	Coefficient	SE coefficient	T	P
Constant	-23.250	5.853	-3.97	0.011
Speed (v)	0.08000	0.01589	5.03	0.004
Feed (f)	85.00	23.84	3.57	0.016
Depth of cut (d)	20.000	5.960	3.36	0.020

S = 0.291976; R^2 = 90.8%; R^2 (Adj) = 85.3%

Table 10. Regression analysis of R_a

Predictor	coefficient	SE coefficient	T	P
Constant	1.8850	0.5237	3.6	0.016
Speed (v)	-0.005877	0.001422	-4.13	0.009
Feed (f)	23.95	2.133	11.23	0.000
Depth of cut (d)	0.6305	0.5332	1.18	0.29

S = 0.261233; R^2 = 96.7%; R^2 (Adj) = 94.7%

Table 11. ANOVA for MRR

source	DF	SS	MS	F	P
Regression	3	420.37	140.12	16.44	0.005
Linear	3	420.37	140.12	16.44	0.005
Residual error	5	42.62	8.52		
total	8	463.00			

Table 12. ANOVA for R_a

source	DF	SS	MS	F	P
Regression	3	9.8655	3.2885	48.19	0.000
Linear	3	9.8655	0.0682	48.19	0.000
Residual error	5	0.3412			
total	8	10.2067			

The normality and constant variance for the models prepared are analyzed by the residual plots drawn and shown in the figures 3 and 4. From the residual plots, it is observed that the residuals are followed the normal distribution and they do not representing any regular pattern.

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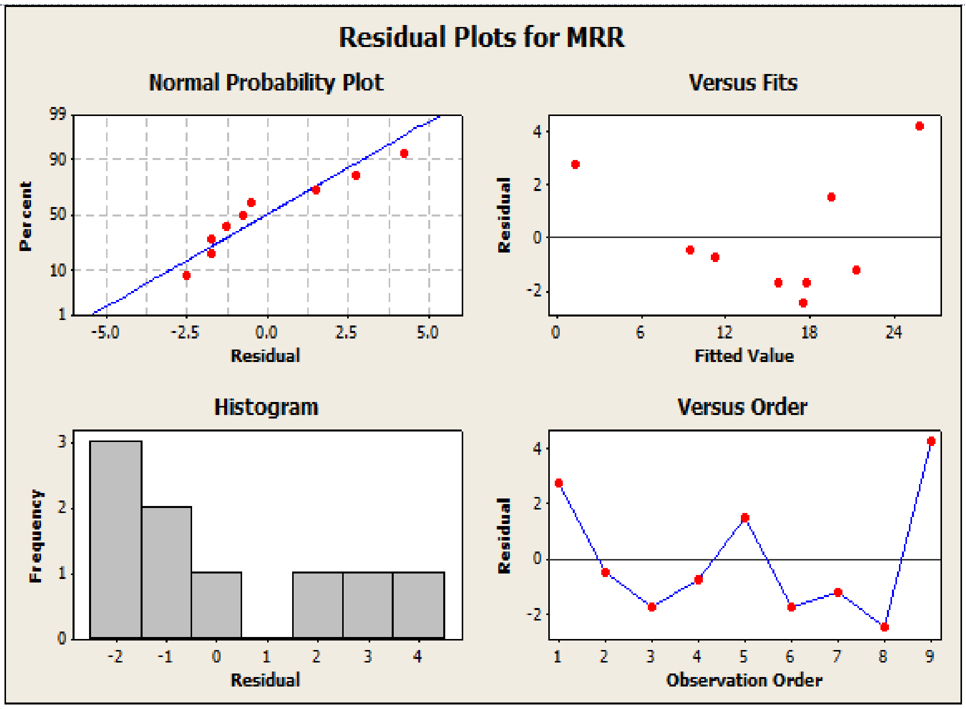

Figure 3. Residual plot for MRR

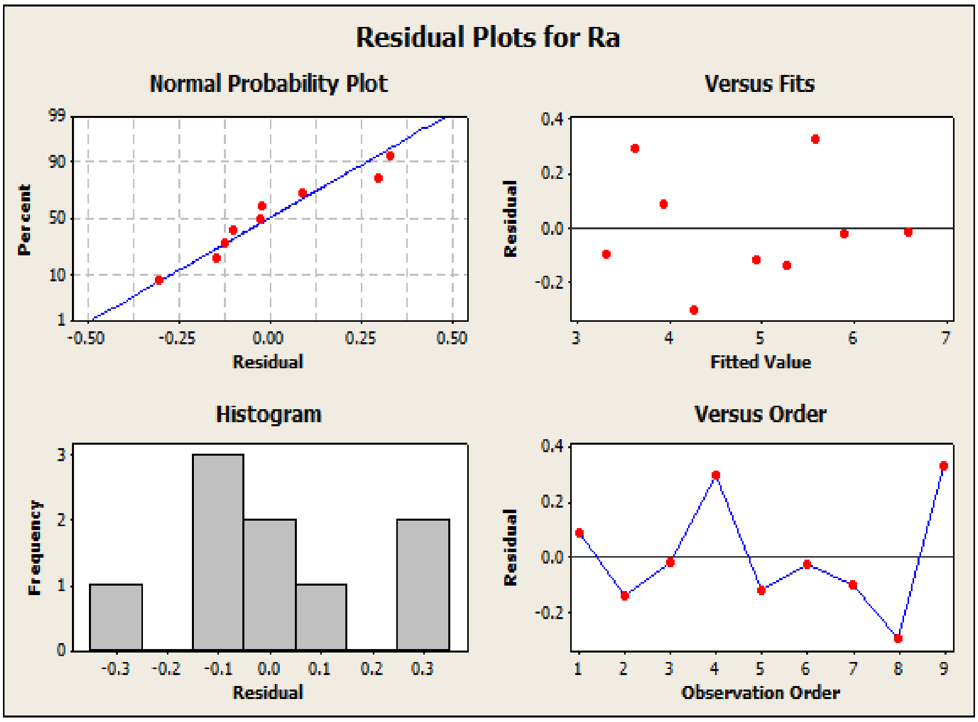

Figure 4. Residual plot for R_a

IV. CONCLUSIONS

- The optimal combination of cutting parameters for material removal rate is obtained at v3-f3-d3, i.e. 250 m/min, 0.2 mm/rev and 0.8 mm.
- The optimal combination of cutting parameters for surface roughness is obtained at v3-f1-d1, i.e. 250 m/min, 0.1 mm/rev and 0.4 mm.

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- The ANOVA results showed that the cutting speed and feed are the most influencing factors in effecting the material removal rate and surface roughness respectively.

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