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Prospects of Machining of Medium Brass Alloy In Turning Process

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Abstract: C35000 (Medium brass alloy) is a difficult to cut material. This paper depicts the effect of material removed and surface finish by the choosing variable parameter. Total number of trials conducted as per levels suggested by Taguchi method. Upon optimization of output parameters optimized value comes out to be 25.69mm^3/min and 16.59 µm. The identified process parameters further derives into machining stability. Trials results further verified with verification test on optimal signal to noise ratio. The optimum value has been determined which is suitable for both output parameters

Keywords: Cutting performance; mechanical properties; C35000 (Medium Brass alloy), MRR, Taguchi orthogonal array, S/N ratio

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1 Introduction

Brass alloys classified as difficult to cut material because of existence of alloying elements. (Wang and Feng, 2002) developed a model considering the input parameters. Results being

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analyzed by various data mining methods and values of response parameters were compared with the data from literature. (Bhattacharya et al., 2009) predicted effects of machining constraint on surface finish and cutting supremacy by employing Taguchi techniques. (Rodzi et al., 2010) exhibited the presentation of coated carbide in machining spheroidal ductile cast iron in different dry environment. (Kaladhar et al., 2011) used coated carbide tool on tungsten substrate while turning austenitic stainless steel. (Selvaraj and Chandramohan, 2010) studied the performance of titanium coating while machining austenitic stainless steel bars. (Çydaş, 2010) studied the recital of cutting tools and the outcome of hardness on machinability while turning of AISI 4340 steels.

2 Experimentation

The tungsten carbide (Gupta et al., 2015) hired for turning of medium brass alloy (C35000) having Ø 25 and 370mm long.

Fig 1.1: Workpiece used for Turning

The turning trials were carried out on a HMT Stallion 100 HS CNC lathe. Tool specification was Back rake angle (0^0), Side rake angle (7^0), End relief angle (6^0), Nose radius (0.8 mm). Geometry is checked with Bevel protector type combination set after each experimental run and accordingly the tool is grinded on the grinding machine. Based up on the literature survey, the amalgamation of uppermost likely level of three process parameters is selected (Kassab and Khoshnaw, 2007) on which machining will be carried out without tool breakdown. Input parameters were chosen by pilot testing as cutting speed (mm/min), feed rate (mm/rev) and depth of cut (mm) and responses were material removal rate and surface roughness.

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Table 1.1: Selected Levels of Process Parameters

Levels	Process Variables		
	Cutting speed (*A*)	**Feed rate (*B*)**	**Depth of Cut (*C*)**
1	60	0.25	0.20
2	80	0.35	0.30
3	100	0.45	0.40

Depending up on three process parameters, Taguchi L_{27} Orthogonal array have been selected. The design consist 27 different combinations of cutting speed, feed rate and width of cut. With MINITAB 16 software the L_{27} was utilized. Design of experiment is shown in Table 1.2 (Hassan et al., 2012).

Table 1.2: Design of Experiment for turning

S. No.	Cutting speed	Feed rate	Width of cut
1	60	0.25	0.20
2	60	0.25	0.30
3	60	0.25	0.40
4	60	0.35	0.20
5	60	0.35	0.30
6	60	0.35	0.40
7	60	0.45	0.20
8	60	0.45	0.30
9	60	0.45	0.40
10	80	0.25	0.20
11	80	0.25	0.30
12	80	0.25	0.40
13	80	0.35	0.20
14	80	0.35	0.30
15	80	0.35	0.40
16	80	0.45	0.20
17	80	0.45	0.30
18	80	0.45	0.40
19	100	0.25	0.20
20	100	0.25	0.30
21	100	0.25	0.40
22	100	0.35	0.20
23	100	0.35	0.30
24	100	0.35	0.40
25	100	0.45	0.20

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26	100	0.45	0.30
27	100	0.45	0.40

Based on the design of experiment given in Table 1.2 the experimental run has been performed out on the CNC lathe machine. The experiments were performed by preparing the workpiece into three piece of the total length on CNC lathe, (Figure 1.2).

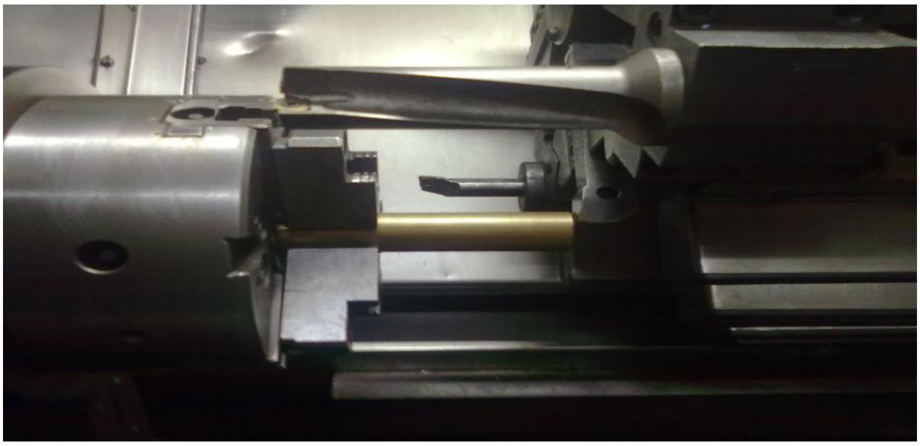

Figure 1.2: Turning of Medium brass alloy

Surface irregularity (Huang and Chen, 2001) was measured using a surface roughness tester and material removal rate is calculated by equation given below:

$$\text{Rate of Material Removal} = \text{Wb} - \text{Wa}/\text{qt}$$

Table 1.3: Measurement of Surface roughness Characteristic Ra (µm)

Exp. No	CS (mm/min)	FR (mm/rev)	DOC (mm)	Trial 1	Trial 2	Trial 3	SR (µm)	S/N Ratio(dB)
1	60	0.25	0.20	3.83	3.81	3.82	3.82	-11.64
2	60	0.25	0.30	3.68	3.67	3.66	3.67	-11.29
3	60	0.25	0.40	3.42	3.41	3.40	3.41	-10.65
4	60	0.35	0.20	3.61	3.60	3.59	3.60	-11.12
5	60	0.35	0.30	2.59	2.58	2.57	2.58	-8.23
6	60	0.35	0.40	2.62	2.61	2.63	2.62	-8.36
7	60	0.45	0.20	2.00	1.99	1.98	1.99	-5.97
8	60	0.45	0.30	2.08	2.10	2.09	2.09	-6.4

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9	60	0.45	0.40	2.73	2.74	2.75	2.74	-8.75
10	80	0.25	0.20	4.07	4.06	4.05	4.06	-12.17
11	80	0.25	0.30	3.68	3.69	3.70	3.69	-11.34
12	80	0.25	0.40	3.71	3.72	3.73	3.72	-11.41
13	80	0.35	0.20	2.54	2.53	2.52	2.53	-8.06
14	80	0.35	0.30	2.41	2.43	2.42	2.42	-7.67
15	80	0.35	0.40	2.61	2.63	2.62	2.62	-8.36
16	80	0.45	0.20	1.43	1.42	1.41	1.42	-3.04
17	80	0.45	0.30	1.34	1.33	1.32	1.33	-2.47
18	80	0.45	0.40	1.58	1.57	1.56	1.57	-3.91
19	100	0.25	0.20	4.09	4.10	4.11	4.10	-12.25
20	100	0.25	0.30	4.05	4.06	4.07	4.06	-12.17
21	100	0.25	0.40	3.98	3.97	3.96	3.97	-11.97
22	100	0.35	0.20	2.72	2.73	2.74	2.73	-8.72
23	100	0.35	0.30	2.73	2.72	2.74	2.73	-8.72
24	100	0.35	0.40	2.67	2.66	2.65	2.66	-8.49
25	100	0.45	0.20	1.64	1.63	1.62	1.63	-4.24
26	100	0.45	0.30	1.49	1.50	1.51	1.50	-3.52
27	100	0.45	0.40	1.30	1.29	1.28	1.29	-2.21

Table 1.4: Calculation of MRR

Exp. No	Cutting speed	Feed rate	Depth of cut	M_1	M_2	M_3	S/N Ratio(dB)	MRR(mm^3/min)
1	60	0.25	0.20	0.056	0.055	0.054	-25.19	0.055
2	60	0.25	0.30	0.052	0.054	0.053	-25.51	0.053
3	60	0.25	0.40	0.057	0.056	0.055	-25.03	0.056
4	60	0.35	0.20	0.054	0.053	0.055	-25.35	0.054
5	60	0.35	0.30	0.056	0.057	0.058	-24.88	0.057

6	60	0.35	0.40	0.054	0.055	0.056	-25.19	0.055
7	60	0.45	0.20	0.057	0.056	0.055	-25.03	0.056
8	60	0.45	0.30	0.054	0.053	0.052	-25.51	0.053
9	60	0.45	0.40	0.056	0.055	0.057	-24.88	0.057
10	80	0.25	0.20	0.057	0.056	0.055	-25.03	0.056
11	80	0.25	0.30	0.054	0.053	0.055	-25.35	0.054
12	80	0.25	0.40	0.056	0.055	0.054	-25.19	0.055
13	80	0.35	0.20	0.058	0.057	0.056	-24.88	0.057
14	80	0.35	0.30	0.054	0.052	0.053	-25.51	0.053
15	80	0.35	0.40	0.055	0.056	0.057	-25.03	0.056
16	80	0.45	0.20	0.055	0.054	0.053	-25.35	0.054
17	80	0.45	0.30	0.056	0.055	0.0554	-25.19	0.055
18	80	0.45	0.40	0.058	0.057	0.056	-24.88	0.057
19	100	0.25	0.20	0.055	0.056	0.057	-25.03	0.056
20	100	0.25	0.30	0.052	0.053	0.054	-25.51	0.053
21	100	0.25	0.40	0.055	0.053	0.054	-25.35	0.054
22	100	0.35	0.20	0.054	0.055	0.056	-25.19	0.055
23	100	0.35	0.30	0.057	0.055	0.056	-25.03	0.056
24	100	0.35	0.40	0.053	0.054	0.052	-25.51	0.053
25	100	0.45	0.20	0.055	0.056	0.057	-25.03	0.056
26	100	0.45	0.30	0.055	0.054	0.053	-25.35	0.054
27	100	0.45	0.40	0.0554	0.055	0.056	-25.19	0.055

3 Results and discussions

3.1 Optimization of Material Removal Rate

Observed data as given in table 1.4 for material removal rate analyzed using the Taguchi optimization technique and two-way ANOVA. The S/N ratio considered by larger the better approach to maximize the MRR:

$$\eta = -10 \log \frac{1}{n} \sum_{i=1}^{n} \frac{1}{y_i^2}$$

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Where η represent S/N ratio, y_i the individual MRR measurements and n is number of reincarnation. To investigate noteworthy involvement of method parameters on recital uniqueness, two-way ANOVA is carried out. Study of the table is done to search the factors that necessitate cautious control. Table 1.5 shows that, the percentage involvement of feed rate i.e. 42.77% where as part of A and C are 17.67% and 28.40% respectively. However the interactions among the various cutting parameters are taken and also the table reveals the percentage contribution of A *B is the largest as compare to the percentage of the rest interactions. From this graph it is evident that feed rate is the main contributing factor.

Table 1.5: Analysis of Variance calculation

S. No.	Factor	Designation	Degree of freedom	Sum of squares	Variance	Statistical parameter	Percentage	Percentage Contribution
1	Cutting speed	A	2	14.08	6.5	1.4	0.3	11.5***
2	Feed rate	B	2	417.18	208.1	44.01	0.000	47.1*
3	Cutting speed*feed rate	A*B	4	45.06	11.2	2.29	0.17	5.1
4	Depth of cut	C	2	17.1	8.7	1.7	0.25	21.2**
5	Cut. speed* depth of cut	A*C	4	5.97	1.49	0.3	0.87	3.7
6	Feed rate* depth of cut	B*C	4	12.9	3.43	0.7	0.62	2.5
	Error		8	28.95	4.825			9.3
	Total		26					100

The equation for rate of material removal= -25.2-0.00173CS+0.437FR-0.092DOC

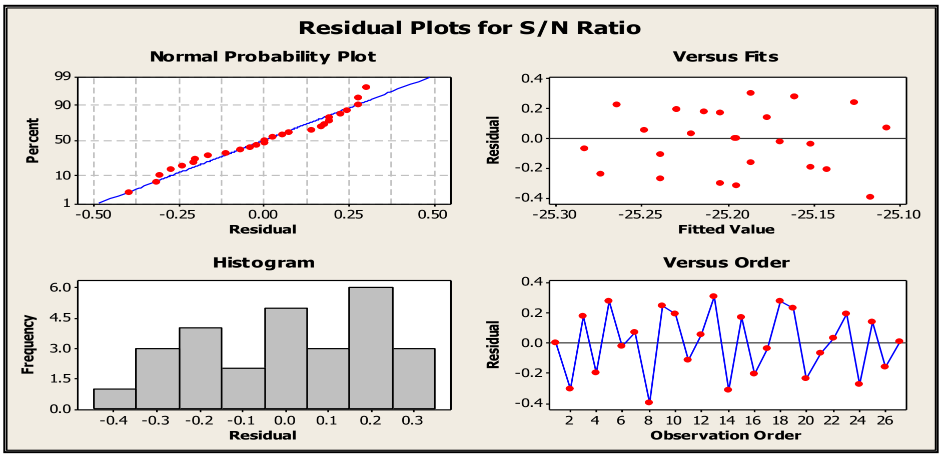

Figure 1.3: Normal Probability analysis on residual for MRR

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Table 1.6: **C**alculation of S/N ratio of rate of material removal

Level	Cutting Seed (A)	Feed Rate (B)	Depth of cut (C)
1	-8.918	-3.022	-7.063
2	-7.221	-8.757	-8.961
3	-8.213	-12.574	-8.329
Rank	4	1	3

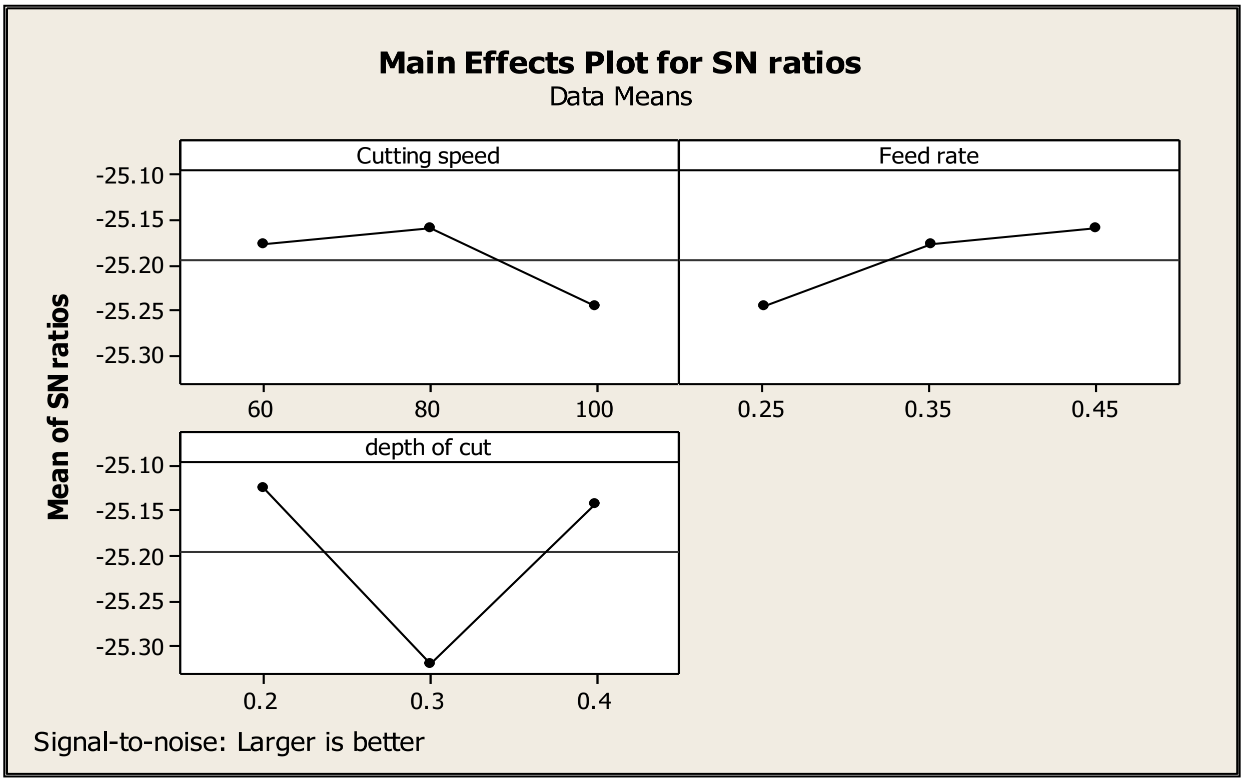

Figure 1.4: Relation representation of process parameters with S/N ratio

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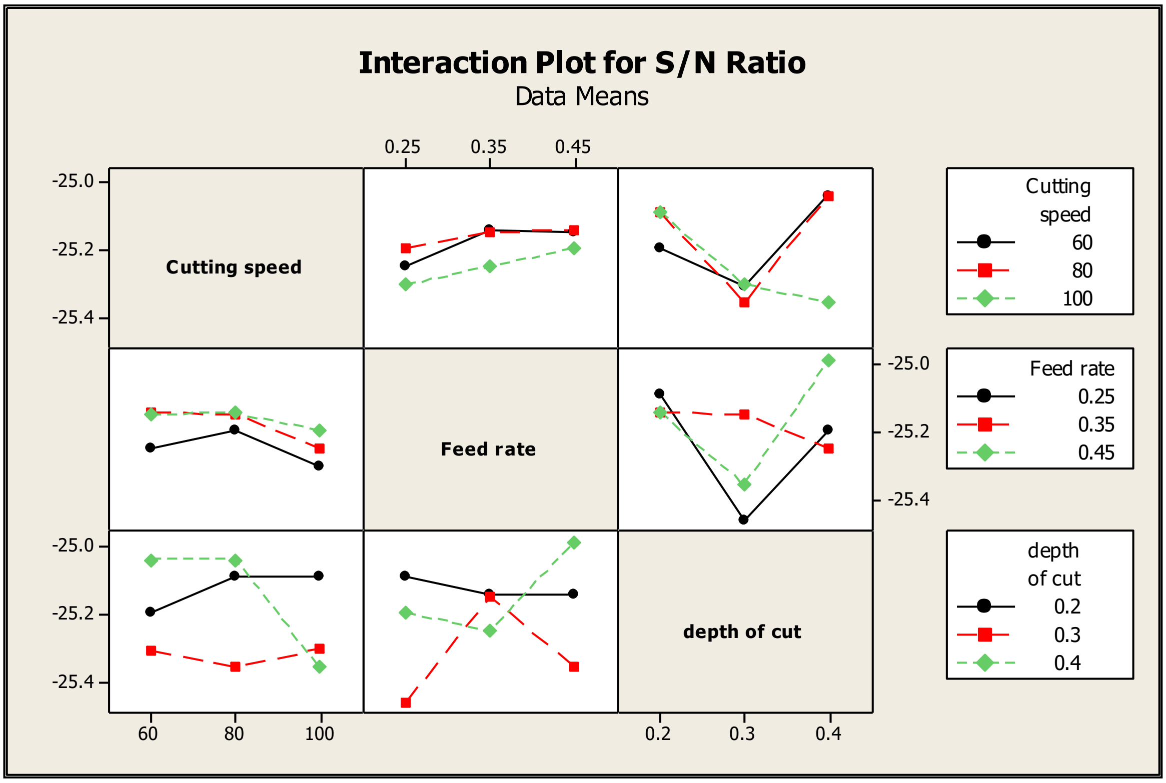

Graph 5.1.1 (d): Interaction Plot for S/N Ratios of MRR

Figure 1.5: Behavior of interaction variables

Figure 1.5: Interaction analysis with S/N ratio

3.1.1 Assurance of Ideal Condition

Both the retort signal by noise fraction is used to calculate optimal levels. The graphs of Figures 1.4 and 1.5 are used to decide the optimum permutation.

3.1.2 Predictive Equation and Verification

Optimized value of surface roughness is predicted by:

$$\eta = \eta m + \sum_{i=1}^{0} (\eta im - \eta m)$$

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$$\hat{\eta}\_MRR = -25.18 + [(-25.51 + 25.18) + (-25.35 + 25.18) + (-25.19 + 25.18)]$$

$$\hat{\eta}\_MRR = 25.69 mm^3/min$$

The healthiness of constraint accumulation is experimentally confirmed. It requires the authentication run at the calculated optimal states. The testing is conducted at the predicted optimum conditions 25.69. Inaccuracy in the opted and investigational value is 0.6%, which is less than 5%, it confirms outstanding reproducibility of the outcome. The optimal parameter set ($A_1B_3C_2$) defines a higher rate of material removal.

Table 1.7: Result analysis

Cutting Parameters	Optimal Values Of Parameters	Optimal Setting Level	Predicted Optimal Value	Optimal Value Of MRR	Experimental Values
Cutting speed (A)	60mm/min	$A_1B_3C_2$	25.69	$8.78<\eta_{MRR}>8.91$	25.03
Feed rate (B)	0.45mm/rev				
Depth of cut (C)	0.3mm				

3.2 Surface Roughness optimization Using Taguchi Method

The S/N fraction obtained by Taguchi's STB loom to reduce the surface roughness:

$$\eta = -10 \log \frac{1}{n} \sum_{i=1}^{n} y_i^2$$

Table 1.7: ANOVA Analysis of Surface Roughness

S.No.	Factors	Designation	DF	SS	V	F	P	% Cont.
1	Cutting speed	A	2	695.51	347.754	44.49	0	21.31
2	Feed rate	B	2	477.36	236.682	30.53	0.001	14.63
3	Cutting speed x feed rate	AxB	4	143.82	35.956	4.6	0.049	4.41
4	Depth of cut	C	2	541.05	270.523	34.61	0.001	16.58
5	Cut. speed x depth of cut	AxC	4	518.63	129.657	16.59	0.002	15.89

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6	Feed rate x depth of cut	BxC	4	242.47	60.618	7.75	0.015	7.43
	Error		8	46.9				1.44
	Total		26	3263.85				100

At Confidence Level = 95%

From this graph feed rate is the main dominating factor

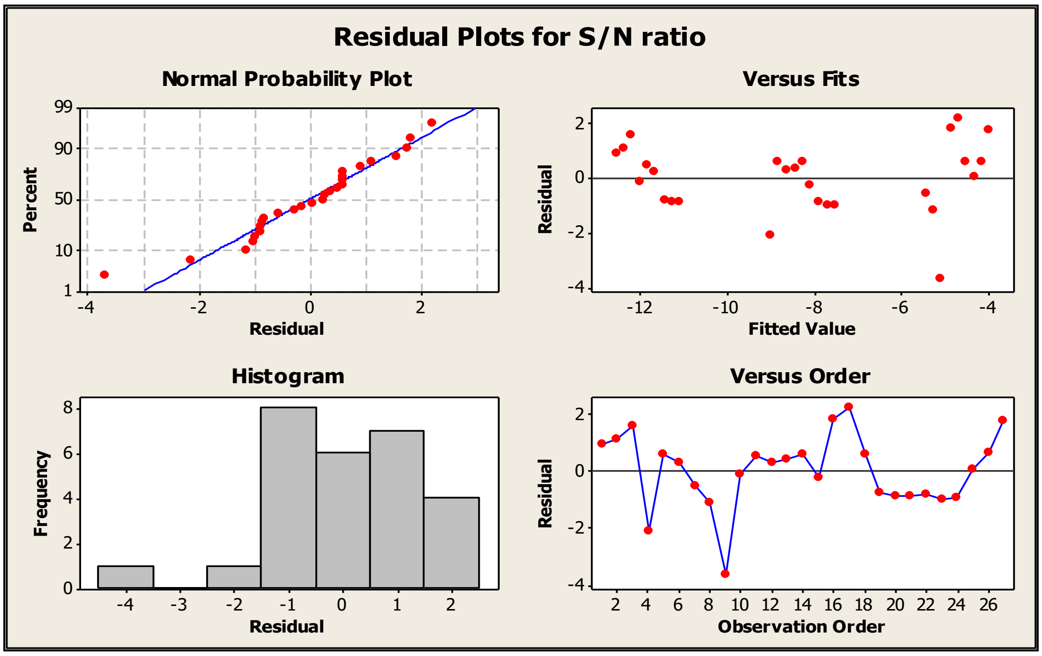

Figure 1.6: First degree polynomial residual analysis

The regression equation is:

S/N ratio of SR = -23.5+0.0281CS+35.8FR+1.72DOC

S = 1.358 R-Sq = 84.84% R-Sq(adj) = 82.8% PRESS = 773.665

Table 1.8: Response Table for S/N Ratios of Surface Roughness

Level	Cutting Speed (A)	Feed Rate (B)	Depth of cut (C)
1	-16.92	-16.97	-15.50
2	-12.91	-10.84	-13.79
3	-4.72	-6.74	-5.26
Rank	4	1	3

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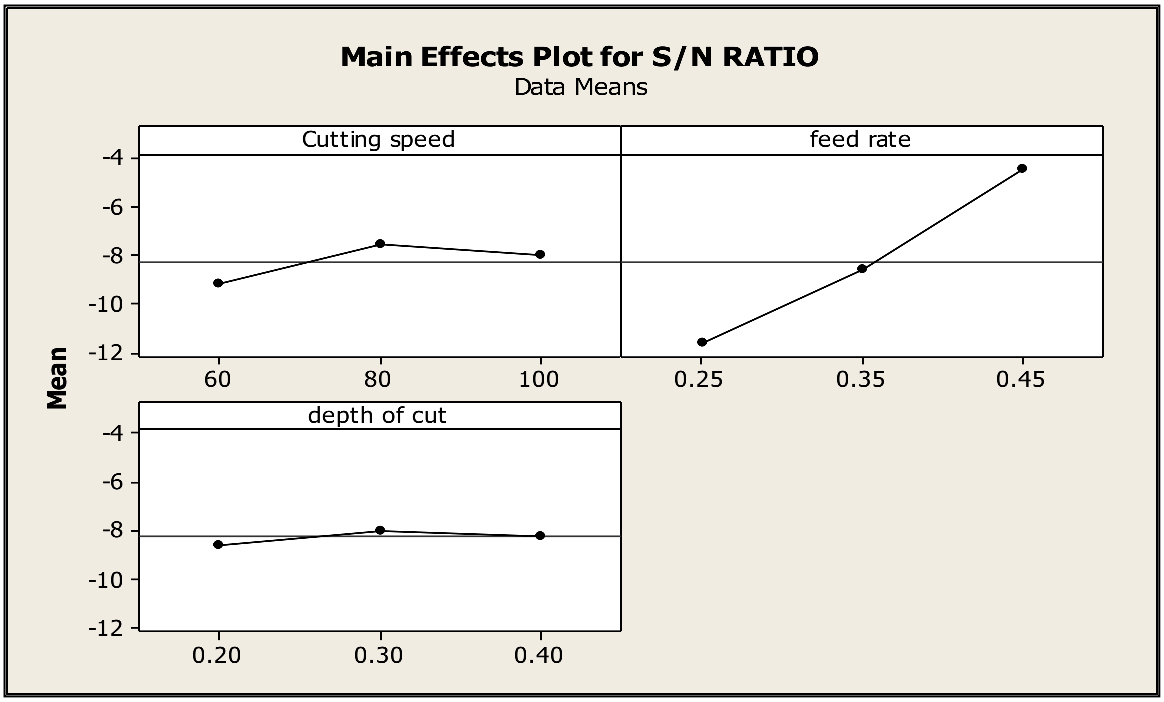

Figure 1.7: Main Effects Plot for S/N Ratios of Surface Roughness

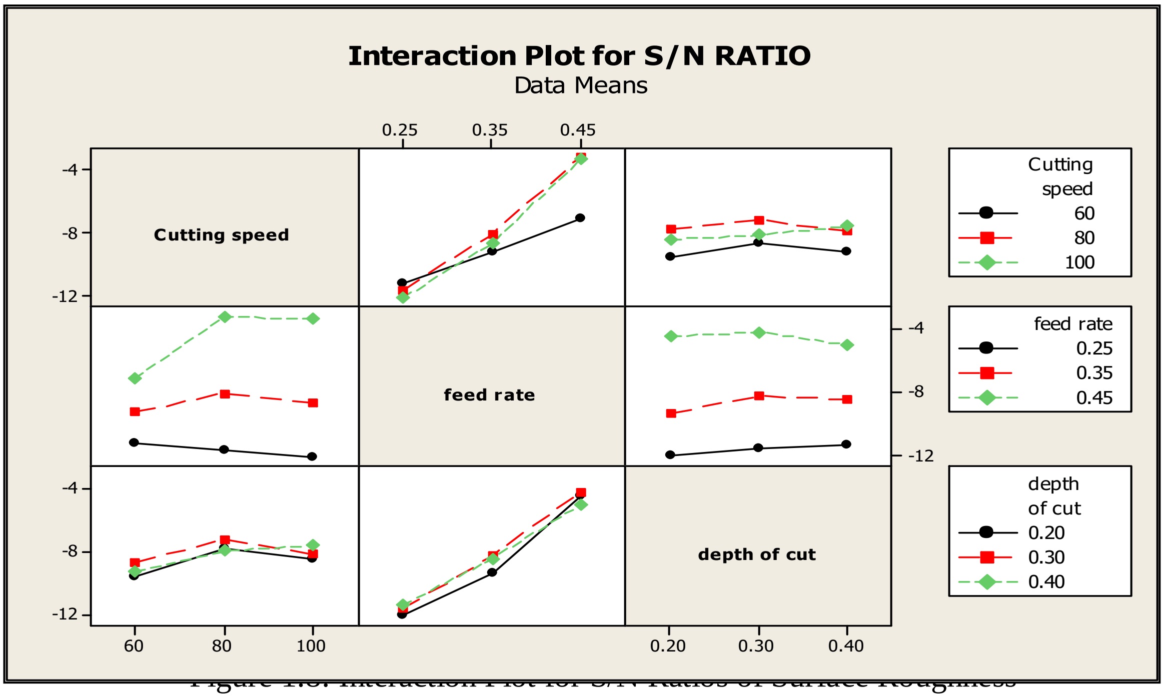

Figure 1.8: Interaction Plot for S/N Ratios of Surface Roughness

3.2.1 Determination of Optimum Condition

Output parameters and S/N ratio are utilized to find out the most favorable conditions. The optimum grouping is $A_3B_3C_1$.

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3.2.2 Predictive Equation and Verification

The anticipated value of MRR at the optimum levels is calculated as:

$$\eta = \eta m + \sum_{i=1}^{0} (\eta im - \eta m)$$

Where η is the total mean S/N ratio ηim is the mean S/N ratio at optimal level and **o** is the number of main design parameters that affect the quality characteristic.

$$\hat{\eta}_{MRR} = -8.26 + [(-11.34 + 8.26) + (-11.12 + 8.26) + (-10.65 + 8.26)]$$

$$\hat{\eta}_{MRR} = 16.59\ \mu m$$

The testing is conducted at the predicted optimum response is 16.59 µm. The miscalculation in the predicted and experimental value is only 3.2%, which is less than 5%, it confirms the excellent results. Higher surface finish is achieved by conducting the machining trials on combination of process parameters i.e., *A3B3C1*.

Table 1.8: Results comparison for surface roughness

Response variables	**Optimal values**	**Optimal level**	**Predicted value**	**Optimal SR(μm)**	**Experimental results**
Cutting speed (A) Feed rate (B) Depth of cut (C)	100mm/min 0.45mm/revs 0.20mm	$A_3B_3C_1$	16.59 μm	$2.3<\eta_{SR}>2.5$	12.25 μm

4 Conclusions

The main conclusions drawn from experimental work are as follows:

1. To optimize the input paremeters in machining of medium brass alloy Taguchi design is appropriate.
2. The significant factors for the surface roughness and material removal rate in turning C35000 is feed rate, cutting speed with the contribution of 47%, 34% respectively.
3. The best possible interaction parameter is between the speed and width of cut with 15% percentage input.

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